Über dieses Buch

Dies ist ein digitales Exemplar eines Buches, das seit Generationen in den Regalen der Bibliotheken aufbewahrt wurde, bevor es von Google im Rahmen eines Projekts, mit dem die Bücher dieser Welt online verfügbar gemacht werden sollen, sorgfältig gescannt wurde.

Das Buch hat das Urheberrecht überdauert und kann nun öffentlich zugänglich gemacht werden. Ein öffentlich zugängliches Buch ist ein Buch, das niemals Urheberrechten unterlag oder bei dem die Schutzfrist des Urheberrechts abgelaufen ist. Ob ein Buch öffentlich zugänglich ist, kann von Land zu Land unterschiedlich sein. Öffentlich zugängliche Bücher sind unser Tor zur Vergangenheit und stellen ein geschichtliches, kulturelles und wissenschaftliches Vermögen dar, das häufig nur schwierig zu entdecken ist.

Gebrauchsspuren, Anmerkungen und andere Randbemerkungen, die im Originalband enthalten sind, finden sich auch in dieser Datei – eine Erinnerung an die lange Reise, die das Buch vom Verleger zu einer Bibliothek und weiter zu Ihnen hinter sich gebracht hat.

Nutzungsrichtlinien

Google ist stolz, mit Bibliotheken in partnerschaftlicher Zusammenarbeit öffentlich zugängliches Material zu digitalisieren und einer breiten Masse zugänglich zu machen. Öffentlich zugängliche Bücher gehören der Öffentlichkeit, und wir sind nur ihre Hüter. Nichtsdestotrotz ist diese Arbeit kostspielig. Um diese Ressource weiterhin zur Verfügung stellen zu können, haben wir Schritte unternommen, um den Missbrauch durch kommerzielle Parteien zu verhindern. Dazu gehören technische Einschränkungen für automatisierte Abfragen.

Wir bitten Sie um Einhaltung folgender Richtlinien:

+ *Nutzung der Dateien zu nichtkommerziellen Zwecken* Wir haben Google Buchsuche für Endanwender konzipiert und möchten, dass Sie diese Dateien nur für persönliche, nichtkommerzielle Zwecke verwenden.
+ *Keine automatisierten Abfragen* Senden Sie keine automatisierten Abfragen irgendwelcher Art an das Google-System. Wenn Sie Recherchen über maschinelle Übersetzung, optische Zeichenerkennung oder andere Bereiche durchführen, in denen der Zugang zu Text in großen Mengen nützlich ist, wenden Sie sich bitte an uns. Wir fördern die Nutzung des öffentlich zugänglichen Materials für diese Zwecke und können Ihnen unter Umständen helfen.
+ *Beibehaltung von Google-Markenelementen* Das "Wasserzeichen" von Google, das Sie in jeder Datei finden, ist wichtig zur Information über dieses Projekt und hilft den Anwendern weiteres Material über Google Buchsuche zu finden. Bitte entfernen Sie das Wasserzeichen nicht.
+ *Bewegen Sie sich innerhalb der Legalität* Unabhängig von Ihrem Verwendungszweck müssen Sie sich Ihrer Verantwortung bewusst sein, sicherzustellen, dass Ihre Nutzung legal ist. Gehen Sie nicht davon aus, dass ein Buch, das nach unserem Dafürhalten für Nutzer in den USA öffentlich zugänglich ist, auch für Nutzer in anderen Ländern öffentlich zugänglich ist. Ob ein Buch noch dem Urheberrecht unterliegt, ist von Land zu Land verschieden. Wir können keine Beratung leisten, ob eine bestimmte Nutzung eines bestimmten Buches gesetzlich zulässig ist. Gehen Sie nicht davon aus, dass das Erscheinen eines Buchs in Google Buchsuche bedeutet, dass es in jeder Form und überall auf der Welt verwendet werden kann. Eine Urheberrechtsverletzung kann schwerwiegende Folgen haben.

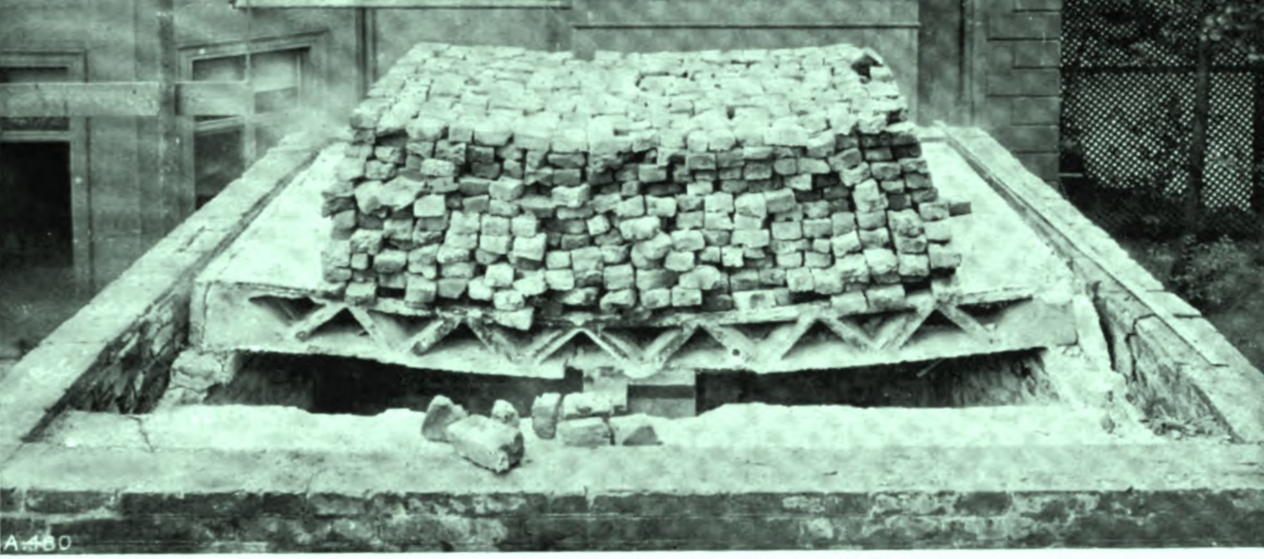
Über Google Buchsuche

Das Ziel von Google besteht darin, die weltweiten Informationen zu organisieren und allgemein nutzbar und zugänglich zu machen. Google Buchsuche hilft Lesern dabei, die Bücher dieser Welt zu entdecken, und unterstützt Autoren und Verleger dabei, neue Zielgruppen zu erreichen. Den gesamten Buchtext können Sie im Internet unter `http://books.google.com` durchsuchen.

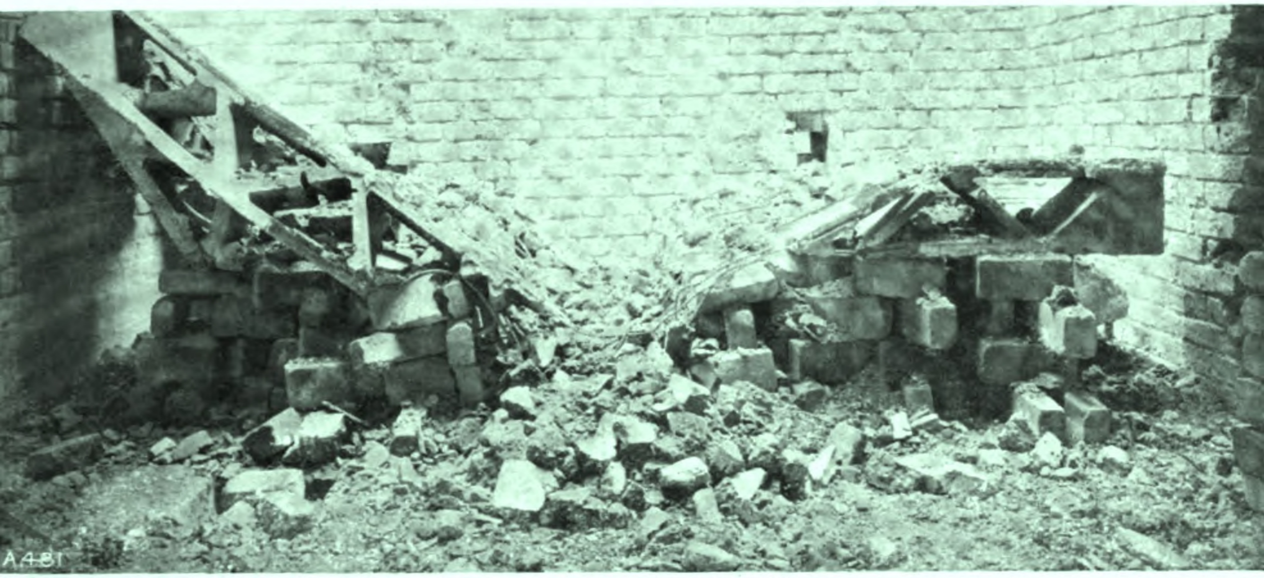
This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

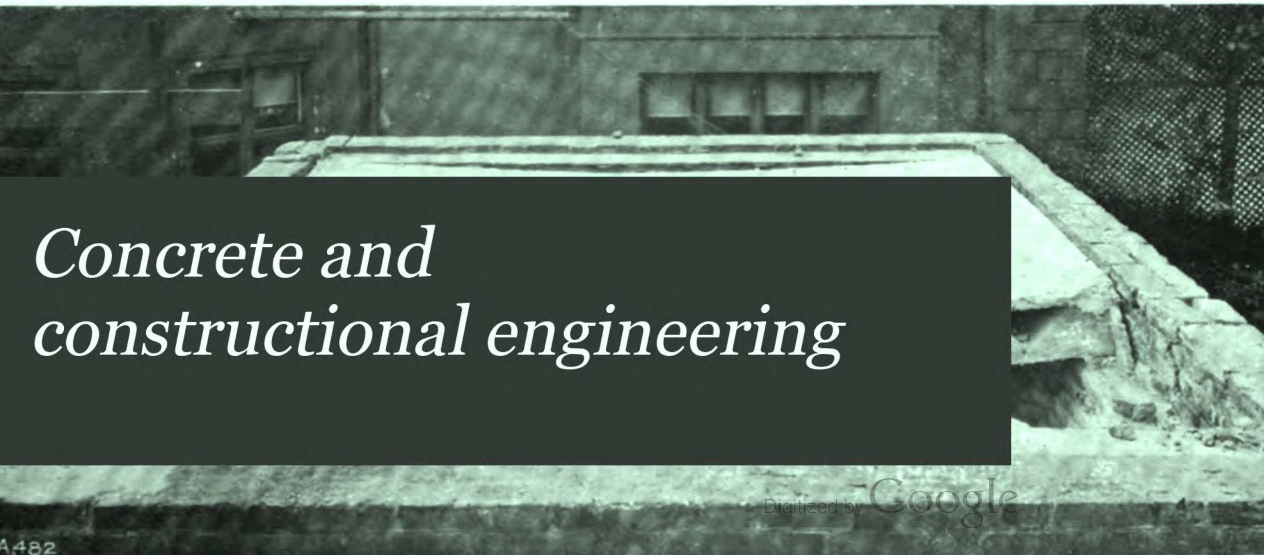
https://books.google.com



MIXED FLOOR IMMEDIATELY AFTER COLLAPSE.



PART OF FLOOR COLLAPSED.



Concrete and constructional engineering

1837
ARTES VERITAS SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUAERIS PENINSULAM AMOENAM CIRCUMSPICE
DEPARTMENT
OF
ENGINEERING

~~Engineering~~
~~Library~~

TA
680
.C78

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

VOL. II. **1907-8.** **Nos. 1 to 6**

A Bi-Monthly Journal for Engineers, Architects and Surveyors—Contractors and Builders—and all Workers in Cement, Concrete, Reinforced Concrete, and Constructional Steel.

INDEX
TO
VOLUME II.

(Nos. 1 to 6).

Published at 57 Moorgate Street, London, E.C.
1907-8.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume II. Published at 57 Moorgate Street, London, E.C. 1907-8.

INDEX.

ARTIFICIAL STONES, METHOD OF MANUFACTURE OF
- Apoenite Artificial Stone ... 64
- Artificial Stones ... 60
- Atlas Stone ... 68
- Beacon Stone ... 66, 156
- Bennett's Improved Granite Stone ... 68
- Chance's Artificial Stone ... 67
- Christie Patent Stone ... 68
- Ellis, John, & Sons', Ltd., Artificial Stone 69
- Empire Artificial Stone ... 64
- Engratic Stone ... 66
- Excelsior Patent Stone ... 66
- Gibbs Bros.' Artificial Stone ... 69
- Hodkin & Jones' Artificial Stone ... 68
- Imperial Stone ... 66
- Imperishable Concrete Masonry ... 68
- Impermeable Stone ... 68
- Lascelles' Concrete ... 68
- McLeod, Malcolm, Artificial Stone ... 69
- Patent Impervious Stone ... 67
- Phillips, A. J., Artificial Stone ... 69
- Ransome's Artificial Stone ... 64
- Silicoted Stone ... 66
- Sorel Stone ... 67
- Stuart's Granolithic Stone ... 66
- Victoria Artificial Stone ... 65, 156
- Ward, B., & Co. Artificial Stone ... 69

CEMENT.
- American Cement Users' Association ... 399
- Brickwork, Portland Cement ... 320
- Cement Bags, Wrongful Use of ... 426
- Cement Manufacture, The Association of Engineers in Charge and ... 399
- Cement Tests, Everyday ... 426
- Cement Trade, Home Office Committee on Wages in ... 393
- Cement Trade, Views of Action of Local Government Board in ... 339
- Cement Uses ... 9
- Colours for Cement and Concrete Work ... 85
- Fictitious Portland Cement ... 340, 341
- Invention of Portland Cement, Some Historical Notes on the ... 456, 457, 458
- Old Country Bridges, Preservation by Patent Cement ... 487
- Portland Cement, Chemical and Physical Aspect in setting ... 24 to 29
- Portland Cement, Fictitious ... 340, 341
- Portland Cement, Package of ... 260
- Portland Cement, Revised British Standard Specification for ... 234, 261, 415
- Portland Cement, Some Historical Notes on the Invention of ... 456
- Portland Cement, The Value of Gauged Neat. By E. P. Wells ... 333
- Sea Water, Behaviour of Cements in. By H. Le Chatelier ... 112
- Setting of Portland Cement. By H. Le Chatelier ... 112
- Setting of Portland Cement. By R. C. Carpenter (U.S.A.) ... 195
- Setting of Portland Cement. By D. B. Butler, A.M.Inst.C.E., F.C.S. ... 24
- Setting of Portland Cement. By Bertram Blount, F.I.C. ... 368
- Setting of Portland Cement, Materials which Retard the ... 195
- Setting of Portland Cement. Summary of Questions debated in previous issues. By Bertram Blount, F.I.C. ... 368

CORRESPONDENCE.
- Calculations, Continental Methods of ... 157
- Calculations, Continental Methods of. By M. De Tedesco ... 254
- Colours for Cement and Concrete Work ... 85
- Local Government Board and Reinforced Concrete ... 85
- Reinforced Brickwork Tanks ... 256
- Reinforced Concrete Committee ... 415

EDITORIAL NOTES.
- Algebraical Symbols, Standardisation of ... 343
- Beam Formulæ, Standard Notation for Reinforced Concrete ... 342
- British Fire Offices and Reinforced Concrete ... 173, 344
- British Government and Reinforced Concrete ... 258
- Cement and the International Testing Association ... 174
- Cement Bags, The Wrongful Use of ... 426
- Cement Tests, Every Day ... 426
- Collapse of Steel Bridge at Quebec ... 343
- Committee of R.I.B.A. on Reinforced Concrete ... 89
- Committee on Reinforced Concrete, Report of ... 175
- Commission, International, on Reinforced Concrete ... 88, 173
- Concrete as a Factor in Building Construction ... 171
- Concrete Aggregates, Commission on ... 89
- Concrete and Fire Prevention Committee ... 424
- Concrete Institute, A ... 423
- Earthquakes, Reinforced Concrete in Countries Subject to ... 171
- Earthquake Shock, Stability of Concrete under ... 87, 171, 317
- Failures of Reinforced Concrete in U.S.A. 2, 173
- Failures of Reinforced Concrete in Rochester, U.S.A. ... 3
- Fire-Resisting Covering to Steel Framing, Concrete as ... 172
- Fire Resistance and Reinforced Concrete ... 172
- Fire Prevention and Reinforced Concrete ... 424
- Learned Associations and Reinforced Concrete ... 259
- Licences and Specialist Systems ... 4
- Local Government Board and Reinforced Concrete ... 2, 87, 257, 339, 423
- Loans on Public Works in Reinforced Concrete ... 2, 87
- Mouchel, L. G., and Partners, Ltd. ... 425
- Mouchel, L. G., *v.* Wm. Cubitt & Co. ... 4
- Obituary Notices ... 90
- Our Second Year ... 1
- Portland Cement, Fictitious ... 340, 341
- Portland Cement, Package of ... 260
- Rochester, U.S.A., Failure of Reinforced Concrete in ... 3
- Ruined Cities, Rebuilding of, in Reinforced Concrete ... 88
- Ship Canal, Manchester, Reinforced Concrete on the ... 425
- Steel Bridge at Quebec, Collapse of ... 343
- Tanner's, Sir Henry, Views on Reinforced Concrete ... 177

GENERAL.
- Aggregates (for Fire Resistance) ... 221
- Articles and Papers at Home and Abroad... 86
- British Fire Pevention Committee, Official Tests by ... 21
- Building Trades Exhibition at Olympia ... 149
- Cement Uses ... 9
- Connecticut Avenue Bridge in Concrete ... 279
- Concrete and Kindred Materials, Investigations on. By R. L. Humphrey, M.Am.Soc.C.E. ... 381
- Concrete, Laws of Proportioning. By Charles F. Marsh, M.Inst.C.E., M.Am.Soc.C.E. ... 291
- Calculations, Continental Methods of, Correspondence on ... 157

Calculations, Edmond Coignet Method of, for Reinforced Concrete ... 54
Calculations, M. Considère's Method of, for Reinforced Concrete ... 55
Calculations, Hennebique Method of, for Reinforced Concrete ... 53
Calculations, Professor Ritter's Method of, for Reinforced Concrete ... 55
Dehydration of Concrete ... 22
Domes at the Westminster Cathedral, The Concrete ... 212
Eastman Kodak Building, Rochester, U.S.A., Collapse of ... 30
Failures in Reinforced Concrete and their Lessons ... 30
Ferro-Concrete Structures. Paper by Charles Scott Meik, M.Inst.C.E. ... 231
Fire in Tooley Street ... 14
Fire Office Rules ... 220
Forms for Concrete Construction. By Sanford E. Thompson, M.Am.Soc.C.E. ... 205
Houses for the United States, Concrete ... 353
Index of Principal Articles in Former Issues 170
Loads and Fire Risks ... 22
London Building Act, Erroneous Definition of ... 13
New Books at Home and Abroad ... 165
Reinforced Brickwork Tanks, Some Early Examples of ... 39, 234
Standard Fire-Resisting Construction in Relation to Rules of Fire Offices' Committee. By F. A. MacDonald (Glasgow) 219
Surface Finish for Concrete. By Henry H. Quimby, M.Am.Soc.C.E. ... 107
Tooley Street Fire, Unprotected Iron Stanchions and Beams in ... 14
Trussed Concrete Steel Company's Handbook 417
Waterproofing Concrete ... 71
Westminster Cathedral, The Concrete Domes at ... 212, 320
Works, Notable, Illustrated in Former Issues ... *Opposite p.* 170

Industrial Notes.
Armoured Tubular Floors ... 336
Seigwart Floor, The... ... 169

Law Cases.
Concrete Mixing Machines ... 315
Fawcett, Thos. C., Ltd. *v.* Orenstein & Koppell ... 315
Ideal Concrete Machinery Co., Patent Action by ... 155
Licensees of Reinforced Concrete Systems... 58
Mouchel and Another *v.* Coignet and Others 139
Mouchel *v.* William Cubitt & Co. ... 58
Piles, British Patent Rights in Reinforced Concrete ... 139

Memoranda.
Admiralty and Reinforced Concrete ... 393
Bonna Pipes for Norwich Water Mains ... 397
Brickwork, Portland Cement ... 320
British Standard Specification for Portland Cement Revised ... 234
Cement Trade, Home Office Committee on Wages in ... 393
Coignet System in England, Reinforced Concrete Work on ... 320
Concrete Aggregates, Special Commission on 486
Concrete Arch Span, The Longest ... 394
Concrete Bags in Sea Work ... 488
Concrete Bridge, Longest Solid ... 394
Concrete and Steel at Fires ... 398
Concrete Review, The ... 155
"Concrete Steel Buildings," Reference Book on ... 320
Concrete, Strength of ... 319
Concrete under Earthquake Shock, Stability of ... 317
Country Bridges, their Preservation by Patent Cement Grouting ... 487
Docks and Wharves at Venice, Reinforced Concrete ... 489
Dover Harbour and Portland Cement Concrete ... 393
Economy of Reinforced Concrete Bridges... 319
Edison and Concrete Buildings ... 486
Engineers in Charge and Cement Manufacture, The Association of ... 399
Engineering Standards Committee ... 234
Groynes, Reinforced Concrete *v.* Timber ... 488
Hennebique Systems in England, Reinforced Concrete Work on ... 319
H.M. Gunwharf, Portsmouth (To be Reconstructed in Reinforced Concrete) ... 400
House of Commons (Questions regarding use and efficiency of Reinforced Concrete in Public Works) ... 392
Ideal Concrete Machinery Co., Patent Action by ... 155
Jamaica, Reconstruction of, in Reinforced Concrete ... 394
Lectures on Reinforced Concrete ... 490
Lilburn and Lucker Bridges in Reinforced Concrete ... 397
Liverpool Building Regulations and Reinforced Concrete ... 490
Mining Town to be Built of Concrete ... 398
Models or Maps, Concrete ... 490
Mouchel, L. G., and Partners, Ltd. ... 491
New Bridge in Reinforced Concrete (Proposed by City Council of Auckland) ... 155
Office of Works and Reinforced Concrete ... 392
Patent Indented Steel Bar Catalogue ... 491
Post Office Building in Reinforced Concrete 234
Reinforced Concrete Jobs, Useful Code of Instruction on ... 399
Reinforced Concrete, Lecture on ... 398
Reinforced Concrete Pavement, A New ... 296
Resistance of Reinforced Concrete Pier in Severe Collision ... 318
Reservoir Cover, A Reinforced Concrete ... 396
R.I.B.A. and Reinforced Concrete ... 486
San Francisco, Concrete in the Rebuilding of ... 393
Sewers, Reinforced Concrete ... 489
Stakeford Bridge in Reinforced Concrete ... 396
Swimming School Bridge in Reinforced Concrete ... 394
Towers, Reinforced Concrete ... 490
Trussed Concrete Steel Co., Catalogue ... 234
United Kingdom Fireproofing Co. ... 491
War Office and Reinforced Concrete ... 392
Water Mains, Reinforced Concrete ... 319
Waterproofing Concrete ... 71, 490
Wooden *v.* Concrete Bridges ... 487

New Uses for Concrete.
Caissons, Reinforced Concrete ... 329
Concrete Timbering for Coal Mines ... 247, 330
Electric Cables, Supports for ... 501
Fly Wheel, A Concrete ... 501
Greenhouse, A Concrete ... 163
Lighthouses in Reinforced Concrete ... 247
Masts for Wireless Telegraphy, Reinforced Concrete ... 413
Mines, Concrete Timbering for ... 247, 330, 500
Mining, Reinforced Concrete in Coal ... 414
Moist Closet in Reinforced Concrete ... 413
Railway Sleepers in Italy in Reinforced Concrete ... 77
Repairing of Brick Masonry, Reinforced Concrete ... 414
Reservoir, A Reinforced Concrete Water ... 164
Safe, A Reinforced Concrete ... 412
Sewers and Pipes in Reinforced Concrete 248 to 253, 407
Ship Repairing, Concrete for ... 164
Shingles for Roofing in Reinforced Concrete 79
Siegwart Cement Mast ... 162
Telegraph Poles, Concrete Bases for Wood 412
Telegraph Poles, Reinforced Concrete ... 492

New Works in Concrete.
Bridge, Kinclaven, in Reinforced Concrete 74
Brooklands Motor Track Bridge in Reinforced Concrete ... 240, 328
Coaling Jetty and Viaduct in Reinforced Concrete ... 70
Coal Silos, Reinforced Concrete ... 411
Colne Bridge, New Reinforced Concrete ... 327
Dyeing and Cleaning Works in Concrete Block and Reinforced Concrete ... 405
Factory Work, Reinforced Concrete ... 323
General Post Office, Reinforced Concrete in New ... 321
Grossmith, Sons & Co.'s Factory on Coignet System ... 323
Harbour at Tangier, The New ... 401
Monarch Laundry Co., Ltd. ... 405
Mushroom System of Reinforced Concrete in U.S. ... 407
Office Building, Pittsburg, in Reinforced Concrete ... 75
Railway Bridge, A Reinforced Concrete ... 504
Reservoir, Downside Abbey Reinforced Concrete ... 324
Retaining Wall in Piccadilly ... 509
Rixdorf-Mittenwalder Light Railway Bridge (Reinforced Concrete) ... 505
Sewers, Reinforced Concrete ... 407
Stamford Bridge, Worcester, in Reinforced Concrete ... 246
Storage Tank at Chelsea in Reinforced Concrete ... 235
Swimming Baths at Chelsea in Reinforced Concrete ... 235
"Tankage" Building in Reinforced Concrete ... 160
Uihlein Building, Milwaukee, in Reinforced Concrete ... 76

Viaduct in Spain, Reinforced Concrete ... 505
Village Hall Constructed in Concrete ... 402
Waldorf Hotel, Reinforced Concrete Floors at the 243
Walnut Lane Bridge, Germantown, Philadelphia, U.S. 505
Warehouse, St. Paul, Minn., in Reinforced Concrete 76

REINFORCED CONCRETE.

A New Pavement in 396
Admiralty and 392
Anderson's Carriage Co.'s Factory in 200
Austria, Historical Evolution of Reinforced Concrete in 265
Beams and Columns, Experiments with ... 473
Beam Formulæ, Standard Notation for ... 342
Boot Factory in Leicester in 309
Boundary Walls in 501
Bridges in, Economy of 319
Bridge, Kinclaven, in 74
British Fire Offices and 173, 344
British Government and 258
Brooklands' Motor Track Bridge in ... 240, 328
Caissons in 329
Calculations for, Continental Methods of 52, 254
Cathedral in Manila in 303
Characteristics of Chief Systems Applied to Buildings in Great Britain 427
Civil Engineers and 6
Coaling Jetty and Viaduct in 70
Coal Silos in 411
Coignet, Edmond, Methods of Calculations for 54
Coignet Systems in England, Work on ... 320
Columns at Watertown Arsenal (Tests) ... 80
Colne Bridge (New Reinforced Concrete) ... 327
Committee, Report of, on 175
Committee of R.I.B.A. on 89
Considère's, M., Methods of Calculations for 55
Docks and Wharves at Venice in 489
Dunstan Jetty, Newcastle-on-Tyne, in ... 192
Earthquakes and 171
Eastman Kodak Building, Rochester, U.S.A. 30
Engineering Conference and 230
Engineering Construction and 490
Engineering Trades and 7
Experiments, Tests with 43
Factory Work in 323
Factory in Portobello in 459
Failures in U.S.A. of 2, 173
Failures in Rochester, U.S.A., of 3
Fatigue of. By Chas. F. Marsh, M.Inst.C.E., M.Am.Soc.C.E. 127
Fires and 16
Fire Insurance Offices and 16
Fire Resistance and 172, 424
Fire-Resisting Buildings, The Application of. By Jas. Sheppard, A.Inst.C.E 13, 371
Fire Tests with 18
General Post Office in 321
Great Britain, Progress of Reinforced Concrete in 5
Groynes, Reinforced Concrete *v.* Timber ... 488
Handbook of Instructions for 417
Hennebique Methods for Calculations for ... 52
Hennebique Systems in England, Work on ... 319
H.M. Gunwharf, Portsmouth, in, Reconstruction of 400
Holland, Historical Evolution of Reinforced Concrete in 345
House of Commons, Questions regarding Use and Efficiency in Public Works of 392
International Commission on 88, 173
Jamaica, Reconstruction of, in 394
Lecture on 398
Lectures on 490
Learned Associations and 259
Lighthouses in 247
Lilburn and Lucker Bridges in ... 397, 488
Liverpool Building Regulations and 490
Loans on Public Works in 287
Local Government Board and
2, 85, 87, 257, 339, 423
Manila Cathedral in 302
Masts for Wireless Telegraphy in 413
Mining, in Coal 414
Moist Closet in ... ... [illegible]
Mushroom System in U.S. 407
National Economy and 7
New Bridge Proposed by City Council of Auckland 155
New French Rules as to 226
Office Building, Pittsburg, in 75
Office of Works and 392
Parkston Quay Extension in 186
Pier in Severe Collision, Resistance of ... 318
Piles, British Patent Rights in 139
Post Office Building in 234
Precautions Necessary in executing work in. By Lieut.-Col. J. Winn, R.E. 98
Progress of, in Great Britain 5
Railway Bridge, A Reinforced Concrete ... 504
Railway Sleepers in Italy in 77
Railway Structures in 233
Rapid Factory Construction in 200
Rawson & Sons, Leicester, Boot Factory in 309
Rebuilding of San Francisco in 445
Recent Contracts in 400
Reinforced Concrete Committee 415
Repairing of Brick and Masonry, for ... 414
Reservoir Construction in 377
Reservoir Cover in 396
Reservoir, Downside Abbey, in 324
Reservoir in, A 164
R.I.B.A. and 486
Ritter's, Professor, Methods of Calculations for 55
Rixdorf-Mittenwalder Light Railway Bridge in 505
Ruined Cities in, Rebuilding of 88
Safe, A, in Reinforced Concrete 412
Sea Defences in 467
Sewers and Pipes in ... ... 248 to 253, 407
Sewers in 489
Ship Canal, Manchester, and 425
Shingles for Roofing in 79
Stakeford Bridge in 396
Stamford Bridge, Worcester, in 246
Storage Tank at Chelsea in 235
Structures, Durability of 230
Swimming School Bridge in ... ... [illegible]
Swimming Baths at Chelsea in 235
Switzerland, in, Historical Evolution of ... 91
Systems Applied to Buildings in Great Britain, Chief Characteristics of
Armoured Tubular Flooring System 434
Bonna System 443
Chain Concrete System 434
Coignet System ... 429, 434, 437, 439, 442, 444
Columbian System 434
Considère System 430, 438, 442
Dawnay System 435
Ellis System 444
Expanded Metal System 435, 439, 444
Hennebique System 430, 435, 438, 440, 442, 444
Hodkin-Jones System 435
Homan System 435
Improved Construction System 431, 435
Indented Steel Bar System 431, 438, 440, 444
Johnson System ... 431, 436, 438, 440, 442, 444
Kahn System 432, 437, 438, 441
Koenen System 437
Lindsay System 437
Monier System 444
Mouchel System 443
Potter System 437
Ridley-Cammell System ... 432, 437, 438, 441
Simplex System 443
Somerville System 437
Weber System 441
Wells System 432, 437, 438, 441
Wilkinson System 437
Williams' System 434, 443
Systems, Licensees of Reinforced Concrete 58
"Tankage" Building in 160
Tanner's, Sir Henry, Views on 177
Telegraph Poles in 492
Tests in, Roof 503
Towers in 490
Uihlein Building, Milwaukee, in 76
Useful Code of Instruction on 399
Viaduct in Spain in 505
Waldorf Hotel Floors in 243
Warehouse in Dundee in 387
Warehouse, St. Paul, Minn., in 76
War Office and 392
Water Mains in 319
Watson, James, & Co., Ltd., Warehouse in ... 387
Wharves and Quays in. By W. Noble Twelvetrees, M.I.Mech.I. ... 119, 186, 273

TESTS WITH CONCRETE.

Armoured Tubular Flooring 375
Beams and Columns, Experiments with Reinforced Concrete. By Chas. F. Marsh, M.Inst.C.E., M.Inst.M.E., M.Am.Soc.C.E. 473
Concrete and Reinforced Concrete Columns at Watertown Arsenal 80
Concurrence of Concrete and Steel 84
Experiments and Tests with Reinforced Concrete, A few. By R. T. Surtees 43
Herbst Armocrete Tubular Flooring, Load Tests of 502
Reinforced Concrete Roof, Tests with a ... 503

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume II. No. 1. MARCH, 1907.

EDITORIAL NOTES.

OUR SECOND YEAR.

WITH the current issue this journal begins its second year. Founded with the object of meeting the growing demand for reliable technical and economic information regarding Concrete, Reinforced Concrete and Constructional Engineering, every effort has been made to fulfil this programme, and it is hoped that our endeavours have met with the approval of the majority of our readers, who, we are glad to see, have increased steadily from issue to issue, and who now count amongst their number not only the leaders of the technical professions concerned and the great contractors, but also many Government and Municipal Departments.

The presentation of information and views would not be difficult in itself were it not for the fact that we lay great stress on reliability, and that we try to reserve our pages for contributors who can speak with real authority and experience.

We believe that our pages have contained much that is valuable during the past twelve months, but we hope during 1907 to improve the contents in every direction.

Perhaps the most difficult problem that has to be faced by this journal, and will be best appreciated by such of our readers as belong to the technical professions, has been to retain absolute independence in respect to the conflicting interests of the various "specialist" concrete systems, contractors and traders who resent criticism.

It is perhaps the fact that we have unhesitatingly dealt with interesting failures in reinforced concrete construction, whilst strongly advocating that method of building, that has caused more comment among our readers than any other particular point in our pages. Fortunately, however, our correspondence shows that our policy in this direction meets with almost general approval, and that it is only in the case of a few all too optimistic enthusiasts among the engineers and among the representatives of the "specialist systems" referred to, that we receive condemnation for this feature of our pages.

We believe, however, that a strong policy favouring all the good points of concrete and reinforced concrete without stupidly glossing over the weak ones, is what will give confidence to the reader and make our journal a necessity.

As to the advertisers in our columns, we are grateful for their support, but fully realise, from our subscription list, that for a journal of moderate circulation their advertisements will probably nowhere in the United Kingdom and our Colonies be seen by a more influential body of readers, for our subscription list can scarcely be surpassed even by old journals, as far as men of real weight and power in the technical professions are concerned.

To all who have assisted this journal in its first year, we would say "Our best thanks"—and we trust the support received will be continued and extended.

LOANS ON PUBLIC WORKS IN REINFORCED CONCRETE.

We have received from a distinguished civil engineer, who practises in the North of England, a letter (which we reproduce in our correspondence column) pointing out the curious anomaly in the practice of the Local Government Board as to granting loans on public works in reinforced concrete, sometimes subject to repayment in 30 years and sometimes in as short a period as 15 years.

The period of 30 years is the usual one for loans upon public works where ordinary methods of construction are used, and thus 15 years is an extraordinary limitation, materially handicapping the application of reinforced concrete.

The Local Government Board has of course its own permanent inspectors, who act as expert advisers on such matters and who may or may not favour reinforced concrete, according to their particular views as to its efficiency. But surely it would be better for this authority to say, if they plainly hold such an opinion, that this method of construction is considered unsuitable by them, instead of "begging the question" by giving what is economically a quite impracticable limitation to the loans.

As our correspondent rightly points out, if a defect is to show itself, it will probably make its appearance at a much earlier period than at the end of the 15th year, so that if permitted at all, the difference between 15 and 30 years is almost immaterial.

But as a matter of fact, reinforced concrete, properly designed and carefully supervised in execution, should be as good, if not better, than any ordinary method of construction upon which 30 years loans are granted. Further, we should almost have thought that the Local Government Board would be well advised not to handicap the efforts of local authorities in their attempts to get their work done economically, by what we fear is merely prejudice. Where municipalities in general have been all too prone to waste money in expensive building operations, the Local Government Board should indeed welcome any effort on their part to keep down the cost of their building operations.

FAILURES OF REINFORCED CONCRETE WORK IN THE UNITED STATES.

It is with regret that we observe there has been a sequence of serious accidents in the United States in buildings where reinforced concrete has been employed, the more so as much capital has been made out of the failures in question by the opponents of this form of construction.

All who know the United States—and most who even only know the country by hearsay—must be fully aware that, what with the rush of rapid building, lax ideas as to the execution of contracts and peculiar views as to supervision on the part of the local authorities, "jerry" building in reinforced concrete is not only common but is almost encouraged, and of course, as we have frequently pointed out, it is in reinforced concrete where careful design, quality of material and fearless supervision counts for much.

Compared with the development of any modern form of construction in the United States, such as steel frame building, we doubt whether there has been, proportionately, an unduly large number of accidents with reinforced concrete, but the fact of course remains that the sequence of accidents has been rapid, that loss of life has been involved, and that every possible effort has been made by the powerful terra cotta interests in that country to misrepresent the causes of these accidents.

THE ROCHESTER FAILURE.

IN two notable cases, namely on November 9th, 1906, at Long Beach, California, and on November 21st, 1906, at Rochester, N.Y., it has been the misfortune of the proprietors of the "Kahn" bars to be affected by the fact of these bars having been employed to a considerable extent on the work concerned.

We have before us most elaborate and well illustrated reports of both accidents, and in this issue we present extracts from one of these reports, as far as the Eastman Kodak Building at Rochester is concerned—*i.e.*, extracts from the most authoritative report available—namely, that referred to us by the Coroner who committed certain persons for trial in connection with this particular accident.

In common fairness to the owners of the building involved, we have also published a report prepared by their own experts, which may be taken in part as a reply to the Coroner's finding. The owners have sent us this report with a most courteous explanatory letter.

We have not had any communication from the owners of the "Kahn" bar in the United States, nor have we so far observed any report or public reply on their part, otherwise it would naturally have found a place in our article.

But as the facts stand before us, and after careful perusal of all matter received on the subject, we would certainly attribute this accident in the main directly to gross negligence in execution, rather than to any question of design.

As to the Coroner's finding, however, which has caused so much comment throughout the United States, and is already beginning to be discussed in this country—namely, that the "Kahn" bar is unsuitable for columns—we would say that we consider firstly, that the "Kahn" bar with its rigid shear members is essentially a suitable bar for beams and floors, in other words, for all horizontal construction where the application of these bars has been properly thought out and where they have been applied with suitable concrete properly filled in. Next, we consider that the condemnation of the "Kahn" bar for columns should not have been published as the Coroner has it, as "a conclusion of fact," but essentially a matter of opinion and, what is more, as a lay opinion. We do not hold the "Kahn" bar as generally applied to columns to be the best form of reinforcement available for vertical supports. The principle advocated by Monsieur Considère is obviously superior. But between advocacy and direct condemnation is a wide step, and with due care and suitable concrete "Kahn" bars have certainly been most efficiently applied in vertical work.

SOME DEDUCTIONS.

WHAT we do wish, however, to very distinctly put forward as a commentary upon the Coroner's finding in respect to the "Kahn" bar column work, is that where building owners employ special commodities, such as bars, lathing and the like for the reinforcement of concrete, it would be wisest to always apply principles of design, and obtain materials most suitable for the specific purpose to which they are to be employed, rather than cling specifically to any one form of design or any one specific commodity. The best designs in reinforced concrete generally comprise quite a number of principles of design and quite a number of commodities, each fulfilling particular duties. A perfect reinforced concrete building might easily comprise columns of the Considère type with Indented bars, beams with "Kahn" bars, floor panels with "Expanded Metal" lathing, walls set out with the Coignet type, and foundations of the piles advocated by Hennebique.

Those associated with specialist systems or special commodities will find their field of activity much wider than at present, directly that unfortunate feeling ceases that a reinforced concrete structure should be entirely on one system only and on no other. Dependency on any one so-called system or commodity is radically wrong.

LICENCEES AND SPECIALIST SYSTEMS.

IN another column we present particulars of the action, L. G. Mouchel, agent for the Hennebique system in England, *versus* William Cubitt & Co., the well-known contractors, on the question of the limitations imposed upon the latter firm by a licence granted them to carry out work on the Hennebique system.

As to the finding of the Court, which, pending appeal, stands as good law, we can only say that whatever the legal aspect may be as to the form of licence in question, the technical and practical aspect is a very different one, for the finding of the Court virtually prohibits Messrs. Cubitt & Co., or any other British licencee of the system, from carrying out any ordinary reinforced concrete work because they happen to hold a licence to carry out work claimed to be protected by certain Hennebique patents in this country.

The validity of any so-called master patent intended to protect or cover a general combination of concrete and steel bars is, of course, problematical, although there are many valuable patents in regard to specific details and special component parts in reinforced concrete. Further, there are endless combinations of steel and concrete all over the world which, although obviously not subject to any proprietary rights, must distinctly compete with the system of construction advocated by the Hennebique firm.

It may be, of course, useful for a firm of contractors (or their employers) to pay 12 per cent. to a specialist firm for the provision of a detailed design in reinforced concrete, although probably any intelligent engineer would provide a suitable design at 5 per cent. In many cases the 12 per cent., by-the-bye, is an extra expense met indirectly by the employer, over and above the 5 per cent. paid for professional design and supervision. The 12 per cent. may or may not buy its worth, but that contractors should, for that privilege, also bind themselves not to carry out any reinforced concrete or similiar work which may possibly be an infringement on a specialist patent, or in competition with it, is scarcely understandable.

It is most regrettable that under the present finding, a number of eminent firms have apparently excluded themselves from executing reinforced concrete work that is open to all comers, for it is to contractors of high repute and great practical experience that orders should preferably be entrusted.

The Progress of Reinforced Concrete in Great Britain During 1906.

In our first issue we published an article from the able pen of Lieut.-Colonel J. Winn, R.E., reviewing the development of concrete as an important factor in constructional engineering and the structural works of civilisation generally.

A year has elapsed since the first issue and we would now deal with progress made in the introduction of reinforced concrete in the British Isles and Imperial Possessions, as also the advance made in the better appreciation of cement uses generally.

Twelve months are but a short lapse of time, but the progress made in that period has been extraordinary, and it is only to be hoped that the year 1907 will be a similarly interesting one as far as this new departure in the constructional work of the Empire is concerned.—ED.

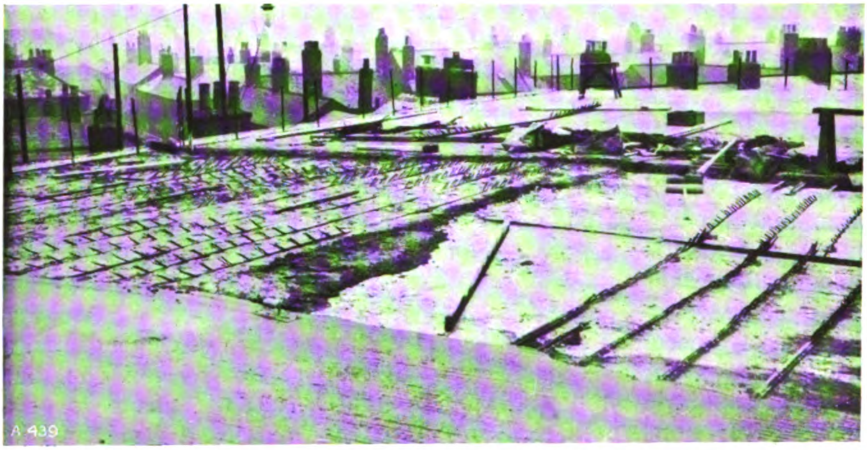
WITH the close of the first year of this journal's existence, a year has ended which will probably be memorable in the history of building construction for the British Isles and our Colonies, for since the spring of 1906, during which this journal appeared, such an interest has been developed in the application of reinforced concrete to building and constructional engineering works, that we can safely anticipate an almost immediate revolution in thought and practice regarding many of the most important structural problems of the day.

For some years France and Germany, and latterly the United States and Italy, have been showing the world the importance of cement uses, and not least among these uses, its application in reinforced concrete, but it has only been during the past twelve months that the members of our technical professions, both civil engineers, surveyors and architects, have suddenly awakened to what a thorough application of cement uses must mean for economical building construction with us. And suddenly—almost too suddenly—cement uses, more particularly in the form of reinforced concrete, have become a daily subject of discussion among professional men, both in the Metropolis, in the provinces, and over-sea. New works in reinforced concrete are springing up everywhere; innumerable ones are being designed, many specialist "systems" of applying the new methods of construction have been put upon the British market, and even our Government Departments are commencing to recognise the value of reinforced concrete for their structural requirements.

For the moment, primary attention is still being paid to reinforced concrete as applicable to the warehouse, the factory, railway station buildings, dock and bridge work, but its uses for the water-works engineering are also just finding favour, and the reinforced concrete reservoir, the water-tower, the cistern and the pipe, have made their appearance; whilst among dock and harbour engineers several varieties of reinforced concrete piles are obtaining quite important positions.

REINFORCED CONCRETE AND THE CIVIL ENGINEER.

What the uses of cement in these modern forms will really mean in the building and general constructional evolution of this country is of course not yet realised, and it is unwise to prophesy, but from the civil engineer's personal point of view, the advent of reinforced concrete construction must be considered a matter of congratulation, for without wishing to say anything hard as to the waning popularity of the architect, and the almost daily reduction of his former fields of activity, it is a fact to which civil engineers cannot shut their eyes, that the great employer of labour no longer goes as much as he used to for advice to the architect, but consults the civil engineer, and with the rapid approach of reinforced concrete buildings, not to speak of steel-frame structures, it will really only remain for the architect at the most to occasionally clothe the exterior of the engineer's design with a suitable decorative garb, and perhaps to also ornament some of the interior. Whilst architects as a body have been living in the world of the past, strong in their conservatism and loth to read and learn the latest, their work has recently been rapidly transferred to the engineer, who is proud to keep abreast with the times, and has realised that, with the exception of the public building, the domestic building, and to a certain limited extent the business building, the great majority of buildings primarily require the attention of the constructional expert rather than that of the artist, and that most building owners prefer an up-to-date technical adviser who can talk economy both as to time, labour and material, to the artist who, all too often, does not grasp the business aspects of structural problems. For the civil engineer the advent of reinforced concrete and steel-frame buildings simply means an enormous addition to his practice, taken mainly from the architectural profession.



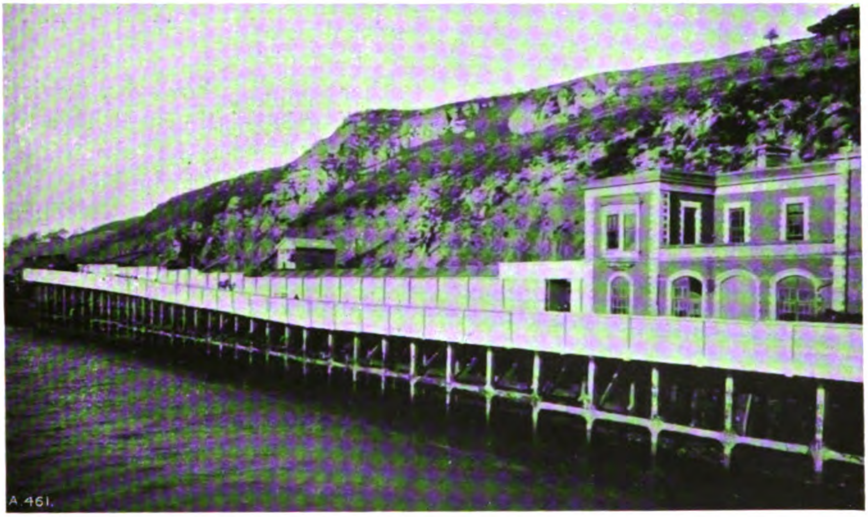
"KAHN BARS" USED AS REINFORCEMENT IN ROOFS.
(A Workshop at Carlisle, 1906.)

REINFORCED CONCRETE AND THE ENGINEERING TRADES.

For the steel worker reinforced-concrete building means an additional output of bars of small sections, frequently of special shapes and elasticity.

For those interested in roofing the advent of reinforced-concrete building means flat roofs with asphalte, "Vulcanite" and similar pliable coverings, and the slater will be superseded by those trades catering for the covering and waterproofing of flat surfaces.

For the cement manufacturer as such, it will mean an enormous rapidly-increasing demand for the very best quality of Portland cement of very fine grinding. For the cement merchants it means an abolition of unreliable foreign grades, and for so-called "Natural" cement or fictitious "Portland" cement it must mean a lingering death, as is already observable from the decreasing imports, for no engineer or architect in his senses will, in time, risk his reputation by allowing anything but the best British brands of cement to be used, and he will gradually learn how to detect the methods of the unscrupulous trader who actually often sells the spurious foreign material in bags bearing the marks of British makers.



QUAY WORK ON THE HENNEBIQUE SYSTEM AT WATERFORD.
(Great Southern and Western Railway, Ireland, 1906.)

REINFORCED CONCRETE AND NATIONAL ECONOMY.

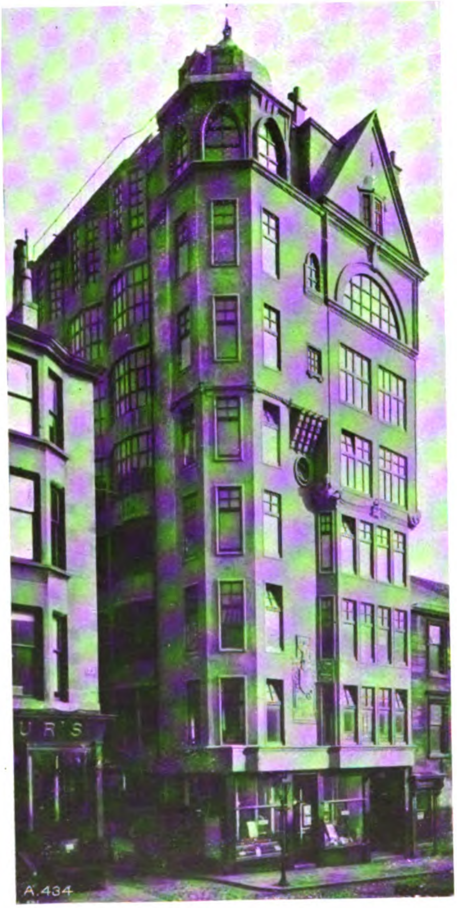
For the great industrial firms and corporations who have much building to do, we think the reinforced-concrete building will not only mean economy in capital expenditure, but a saving in maintenance.

For the fire insurance corporations taking premiums on structures where reinforced concrete of suitable aggregate is properly applied, it will mean a lessening of the fire hazard of the building and of its contents.

For the steel worker reinforced-concrete building means an additional output of bars of small sections, frequently of special shapes and primarily associated with the engineering professions and industries.

SAFEGUARDS AGAINST BAD WORK.

There are still, of course, dangers to be avoided, particularly the danger of work in reinforced concrete being supervised by unskilled men, or, what is sometimes worse, self-opinionated specialists whose obstinacy prevents their realising some of the early faults of this method of construction. Again, it may be scamped and carried out by the "jerry" contractor. The possibility of certain classes of accidents will have to be legislated against. On the other hand, however, existing building legislation will have to be altered to meet the advent of the reinforced-concrete building, which is at present much handicapped in London and many provincial districts in Great Britain. Certain rules as to municipal loans on works of reinforced concrete will have to be modified and other changes in official practice will have to take place.

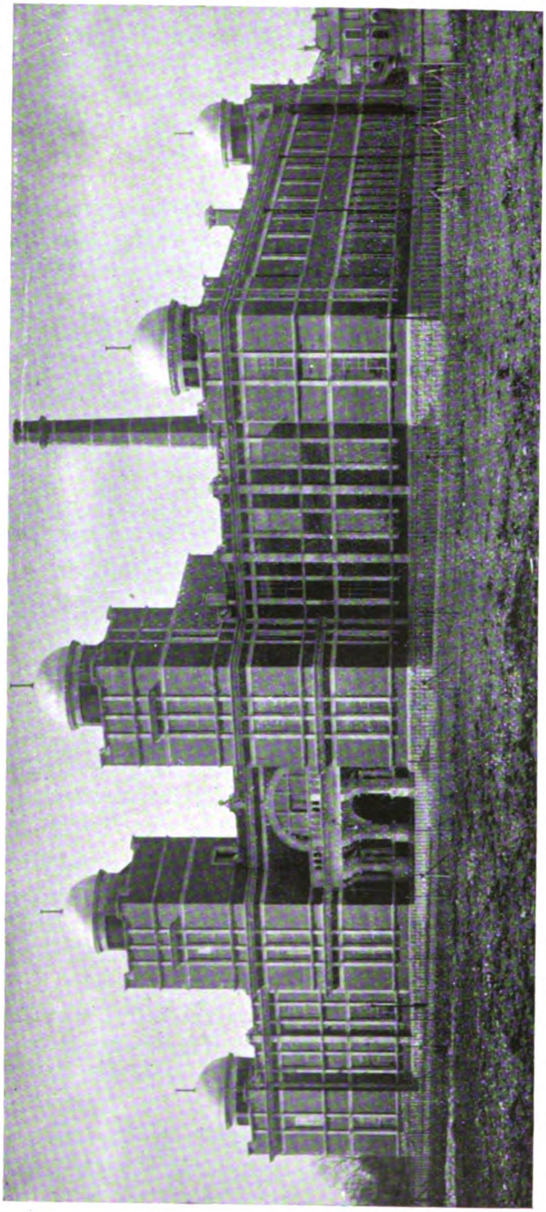


Reinforced Concrete Business Premises on the Hennebique System.

(No. 172 Hope Street, Glasgow, 1906.)

RESEARCH WORK AND STANDARDISATION.

At the present moment, some of the necessary safeguards are no doubt being considered by the Reinforced Concrete Committee constituted by the Royal Institute of British Architects, upon which, however, the great civil engineering interests are, unfortunately, not represented, whilst the few individual civil engineers who are associated with this Committee's work can scarcely be deemed to have had much, if any, practical experience of the subject they have under consideration. But, no doubt, the steps taken by this Committee, which has the benefit of a particularly able architect chairman in the person of Sir Henry Tanner, I.S.O., will lead to some more representative body, such as the Engineering Standards Committee, taking up the subject in such a manner, too, that the great experience on the metallurgical side of the Iron and Steel Institute, and on the fire protective side of the British Fire Prevention Committee, are taken fully into account.



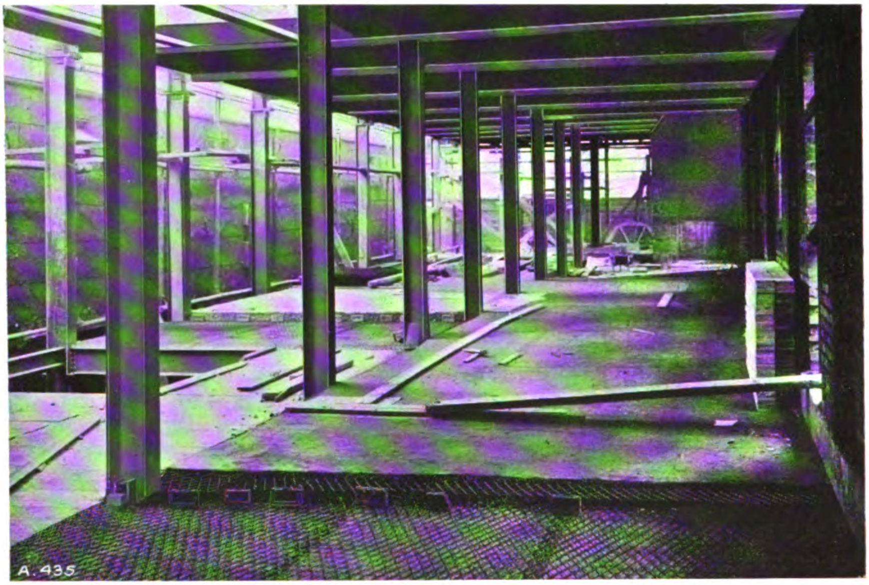
Reinforced Concrete Floors and Roofs for Government Buildings.
(Designed by E. P. Wells for the Stuart Granolithic Stone Co.)
(The School of Electricity, Chatham, 1906.)

We may also, in time, look for some complete and authoritative summary of the results of the world's research work regarding reinforced concrete in structural work, which should materially affect any requirements as to safeguards, for the International Association for Testing Materials is taking the matter up, and may be expected to deal with it with that thoroughness with which it has already dealt with various subjects.

OTHER CEMENT USES.

We shall probably also in due course be having research work in respect to other matters appertaining to reinforced concrete and cement uses, not necessarily connected with structures. There are so many minor uses that still require consideration, experiment and standardisation. To take the mere question of the reinforced-concrete railway sleeper, which seems to be gradually increasing in favour in different Continental countries and in certain distant parts of the world. The telegraph post, the fence post, and innumerable other minor uses come to our minds, which are adapted for use in various districts, particularly in the British

Isles and our Colonies. Then, again, there is that new cement use in which little or no reinforcement is applied, namely, that of the hollow concrete block, which has been rapidly finding favour in the United States, and in respect to which, we believe, there are already several concerns being established in this country, who are providing them primarily for cottage and rural property, where bricks are expensive, and yet the necessary aggregates can be cheaply obtained and cement brought to the spot by cheap means of transportation.



"Expanded Metal" used as a Reinforcement in Warehouse Floors.
(Messrs. Todd, Burns & Co.'s Premises. Dublin, 1906.)

THE "CEMENT AGE."

Altogether, the more one looks into this question of the application of Portland cement with various aggregates, and with or without various forms of reinforcement for special purposes, the more one realises that the advent of a Cement Age—or as some call it, a Concrete Age—is really upon us, and, as indicated above, that the enthusiasm and interest with which the subject is being dealt with in many directions, bids fair to give us the general use of these modern forms of construction in an extraordinarily short space of time.

SOME PROBABLE EFFECTS OF THE "CEMENT AGE."

In three directions the advent of the Cement Age will probably mean a considerable revolution in thought. In the first place, the civil engineers will have to re-learn much as to methods of calculation and questions of design. In the second place, the cement maker will have to work hard to cope with the growing demand for improved quality and greater fineness, and in the third place, the steel maker will have to conceive economical methods for turning out rapidly and regularly the small sections of steel required by a steel of higher elasticity. Of these three parties, the one who is, we hold, best situated for this evolution of thought is the cement maker. For the evolution in producing the necessary binding material during the last five or six years among the leading cement makers on the Thames and Medway has been phenomenal, and the quality of the cement and its fineness quite beyond anything that ever used to be hoped for. All countries have, to our mind, been outstripped. The Germans, we will confess, were somewhat in advance of us at the close of the last century, but now we not only hold our own in this direction, but have surpassed anything that is being produced on the Continent or in the United States, with the result that the really first-class British product should command the world's market on the question of quality alone.

INDEPENDENT PIONEER WORK IN REINFORCED CONCRETE.

But to refer to our opening sentences, an evolution of thought in the direction of cement uses, and reinforced concrete in particular, has occurred, and it has occurred curiously, very suddenly in the twelve months that have just passed. How this evolution should have come about so suddenly and so strongly it is difficult to tell, more particularly as one could almost date the evolution of thought and interest to specific months. But we believe that the change may be in a way attributed to a small coterie of men—or perhaps a few single individuals—who, when they take up a subject enthusiastically, seem to drive it home and popularise it.

The efforts of these pioneers, we believe, have been more successful by their having kept aloof from the representatives of the various so-called "systems," more particularly those worked by foreigners, whose ways—in every direction—are anything but in accordance with British traditions. These pioneers have treated the subject of reinforced concrete as a professional one, open to all of technical training who care to study the question, in no way subservient to monopolies and scarcely affected by patents. They have not stinted praise or encouragement when some useful specialist peculiarity or detail, such as a bar section or a stirrup, merits a patent right, earned by true inventive genius. But these pioneers have also called "a spade a spade" where pretentious foreigners attempted to monopolise reinforced concrete.

A WORD OF WARNING.

A word of warning must, however, now be sounded. Accidents and failures in reinforced concrete are getting fairly common; financial miscalculations as to its economic value are being discussed, the "infallibility" of a certain class of specialist is being doubted, and generally

---

AS TO OUR ILLUSTRATIONS:—

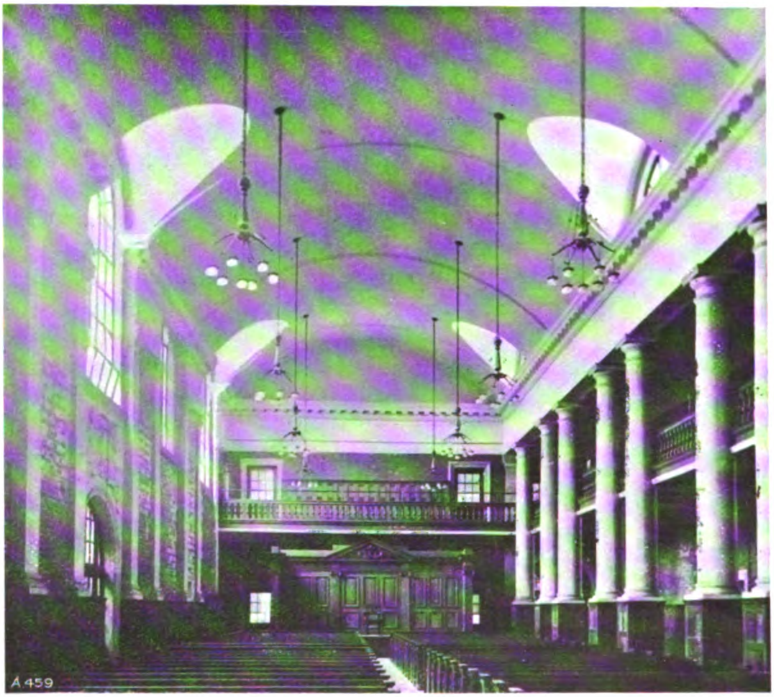
The two works on the Hennebique System on pages 7 and 8, were carried out by the Yorkshire Hennebique Contracting Co., Ltd.: the work in which "Kahn" bars were employed by Stephen Easten, Ltd., Newcastle-on-Tyne, and the work in which the Expanded Metal lathing was employed was carried out under the direction of the New Expanded Metal Co., Ltd.

various negative points as to reinforced concrete are becoming more apparent than during the first flush of enthusiastic propagation.

We have from the outset warned our readers that reinforced concrete is not applicable to *all* structures, neither technically nor economically.

We have warned the architects and engineers not to trust to specialist agents or contractors for calculations, but to use their own brains or call in *independent* professional advice. We have pointed out the necessity for the most rigid supervision of all materials and workmanship and the absolute need for the work to accord correctly with the approved plans. We have quoted failures with a view of affording object lessons against negligence. We trust our efforts to prevent such an excellent form of construction as reinforced concrete having a set-back in this country will have effect.

Whilst delighting in the progress made during the past twelve months, we cannot but again warn our professional readers as to careful independent examination of traders, the specialist's proposals and the rigid supervision of materials and work. To the contractor we would repeat that "cutting things fine" does not pay in reinforced concrete; whilst to the specialist in "systems," we would remind him that Great Britain only stands humbug and bluff to a point.



INTERIOR CONSTRUCTIONAL WORK IN REINFORCED CONCRETE.
(Designed by E. P. Wells for the Stuart Granolithic Stone Co.)
(*New Grammar School, Newcastle. 1906.*)

The Application of Reinforced Concrete for the Construction of Fire-Resisting Buildings

By JAMES SHEPPARD, A.Inst.E.E.

Surveyor to the North British and Mercantile Insurance Co.

Our views as to the fire resistance of reinforced concrete have been presented before. We advocate its use for fire-resisting purposes, but with certain distinct limitations as to the nature and size of the aggregate employed, and the thickness of the protective covering afforded by the concrete to the metal rods. We are emphatically of the opinion that the protection given to the rods by most specialists, when not controlled by independent authority, is entirely insufficient, and that the requirements of the Fire Offices Committee in this country, though preferably those of the United States, should be strictly adhered to. That reinforced-concrete building construction should, as a rule, have advantages over the ordinary forms of factory, mill and warehouse construction is too obvious to mention, but should reinforced concrete be employed for buildings where large stacks of highly combustible materials are to be stored, the building owners will be under an entire delusion as to the safety afforded if the ordinary precautions of concrete and covering are not strictly observed. We are indebted to "Engineering" for two of our illustrations, Figs. 5 and 6.—ED.

THE history of so-called "fire-proof" buildings records long lists of lamentable failures, discreditable to their designers and constructors, who apparently believed that the use of incombustible materials was alone sufficient to secure a fire-resisting structure, and therefore neglected to give any consideration to changes, caused in most materials by the action of fire, heat and water, which inevitably come into operation on the burning of warehoused goods, for the protection of which buildings are provided.

ERRONEOUS DEFINITION OF THE LONDON BUILDING ACT.

Unfortunately, this belief is encouraged by the schedule of materials deemed to be fire-resisting for the purposes of the London Building Acts, 1894, 1898 and 1905. This schedule includes granite, stone, iron, steel, slate, ballast, and any combination of concrete and steel or iron, without qualification of any kind, except with regard to slate, the use of which for fire-resisting purposes is limited to coverings or corbels. It is also provided that the stone used for floors must not be exposed on the underside and not supported at the ends only.

All experience shows that the materials named, although incombustible, are not fire-resisting, as they rapidly lose strength, expand, contract, twist or break up under the sudden changes of temperature that occur during a fire, unless protected with other suitable non-conducting and incombustible material.

The schedule is also inconsistent, for hard timber and iron used in combination for fire-resisting purposes are both required to be protected against fire by other incombustible or non-conducting external covering, not less than 2 in. thick for the iron, and not less than 1 in. thick on iron lathing for the hard timber. Reference to actual fires will definitely prove that steel or iron beams and posts bolted together with flitches of hard timber without other protection are far more fire-resisting than any similar structures of steel or iron only, yet the latter are allowed in combination with concrete having even ballast aggregates without any provision for the due protection against fire of the iron or steel used.

THE TOOLEY STREET FIRE.

A notorious example of the failure of unprotected iron stanchions and beams, supporting brick-arched floors 9 in. thick, occurred in the great Tooley Street fire of June, 1861, which is selected for comment because definite statements by responsible officials with regard to it are available.

The building known as Hayes Warehouse, as given in evidence by the district surveyor before a Parliamentary Select Committee on 4th July, 1867, had a capacity about three times greater than the limit allowed by the Metropolitan Building Act, 1855, in force when the warehouse was erected. The building was constructed with cast-iron posts and girders about 13 ft. apart, and brick arches 9 in. thick between the girders.

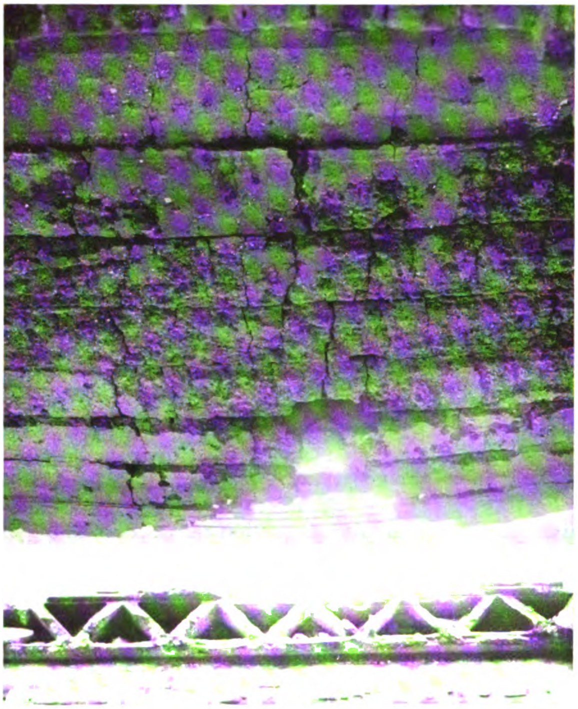


FIG. 1. A VISINTINI FLOOR AFTER LONDON (B.F.P C.) FIRE TEST.

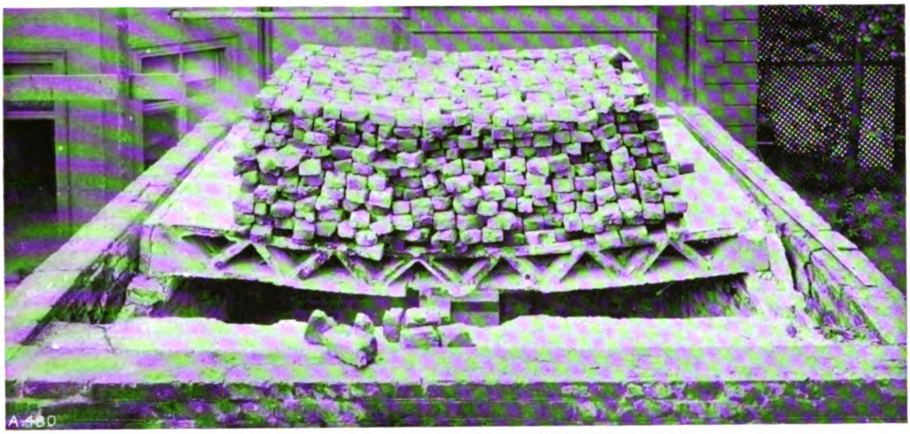
Floor on the Visintini system, tested at the British Fire Prevention Committee's Testing Station on Aug. 12th, 1903, comprising one bay 10 ft. by 10 ft., resting on brick walls. The maximum deflection prior to collapse was 5½ in. The collapse took place at 1 hour and 47 min. The load during fire was 224 lbs. per sq. ft. Duration of fire was 1 hour 47 min., up to temperatures of over 1800° Fahr., followed by application of water for 2 min. (after collapse).

This district surveyor, Mr. Robert Hesketh, took the case before a magistrate on the question of illegal capacity; the magistrate, however, considered that the horizontal divisions were according to the Building Act, and in effect decided that brick floors supported on cast-iron girders and posts are equal to brick party walls.

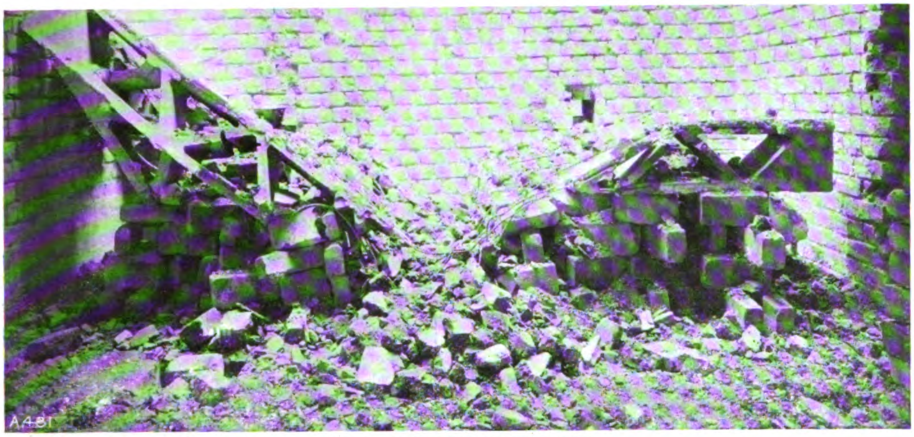
The district surveyor having transferred his responsibility to the magistrate did not take the case further, so the warehouse remained undivided, and was stored with combustible merchandise, ultimately largely contributing to the fatal and disastrous conflagration of June, 1861, by which it was entirely destroyed, every one of the floors falling in, allowing the complete combustion of their contents.

Evidence was also given before the same select committee by Mr. Charles Freeman to the effect that, while the so-called fire-proof construction described was useful for office and domestic buildings, it was quite inadequate to prevent the progress of fire in buildings stored with merchandise, and that there is very little difference between cast and wrought-iron—cast-iron flies, wrought-iron bends.

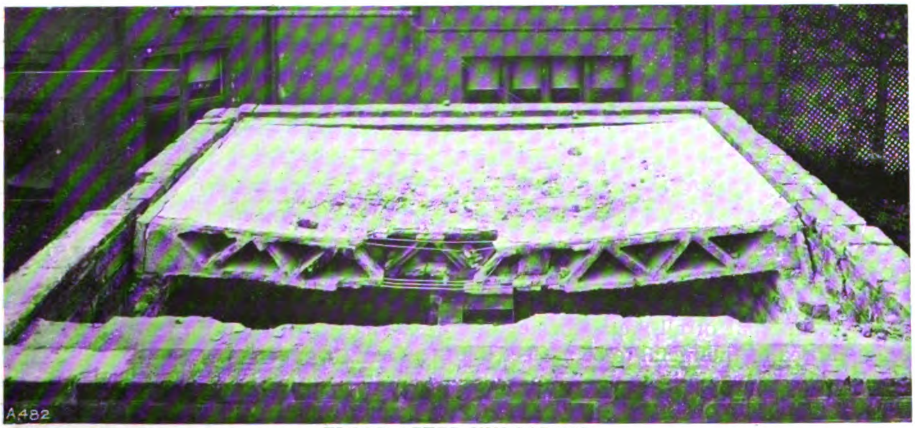
The above magisterial decision was allowed to stand and was extensively acted upon with further disastrous results until 1894, when, on a case being taken before the Court of Queen's Bench, it was finally decided that a so-called fireproof floor was not a party wall.



MIXED FLOOR IMMEDIATELY AFTER COLLAPSE.



PART OF FLOOR COLLAPSED.



FLOOR AFTER UNLOADING.

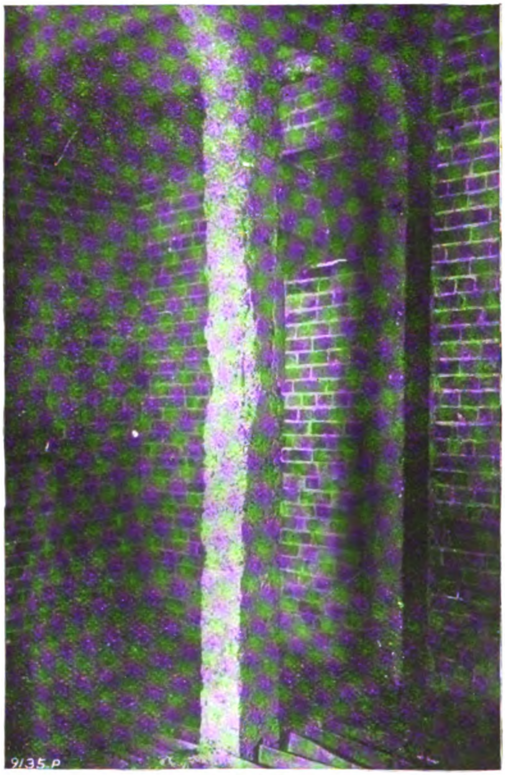
FIGS. 2-4. FLOOR ON THE VISINTINI SYSTEM AFTER LONDON (B.F.P.C.) FIRE TEST.
(For particulars see page opposite.)

REINFORCED CONCRETE.

The failures under actual fires of numerous "fire-proof" buildings have been referred to with the object of emphasising the need for giving careful consideration to the conditions required to secure satisfactory resistance to fire. The necessity for this is in no way lessened by the modern method of combining steel and concrete known as reinforced concrete, concrete-steel, ferro-concrete, armoured concrete and other similar names. All these systems combine rods, bars, bands, or network of steel, having comparatively small sectional areas, with concrete, in such a way that the steel takes all tensional strains and offers resistance to sheer, leaving the concrete chiefly to resist compression, thus advantageously uniting the full strength of both materials.

Such combination of steel and concrete provides a new material for constructional purposes, and undoubtedly affords facilities for the erection of buildings of an exceptional fire-resisting character; but to secure this desirable end, the effect of fire, heat and water on the materials used, both separately and in combination, must be duly considered and provided for.

Heat reaching steel members at any point is conducted through the whole length of the rod, while the concrete, owing to its lower conductivity, may be affected at one point only; in this way internal strains may be set up leading to disastrous results.



From "Engineering."

FIG. 5. A HENNEBIQUE SUPPORT AFTER NEW YORK (C.U.) FIRE TEST.
(Described on page opposite.)

ENCOURAGEMENT AFFORDED BY THE FIRE INSURANCE OFFICES.

The fire insurance offices have not been slow to recognise the possibilities of reinforced concrete construction, both in this and other countries, and have issued rules for the guidance of clients who may desire to obtain all advantages afforded by the provision of reliable fire-resisting buildings.

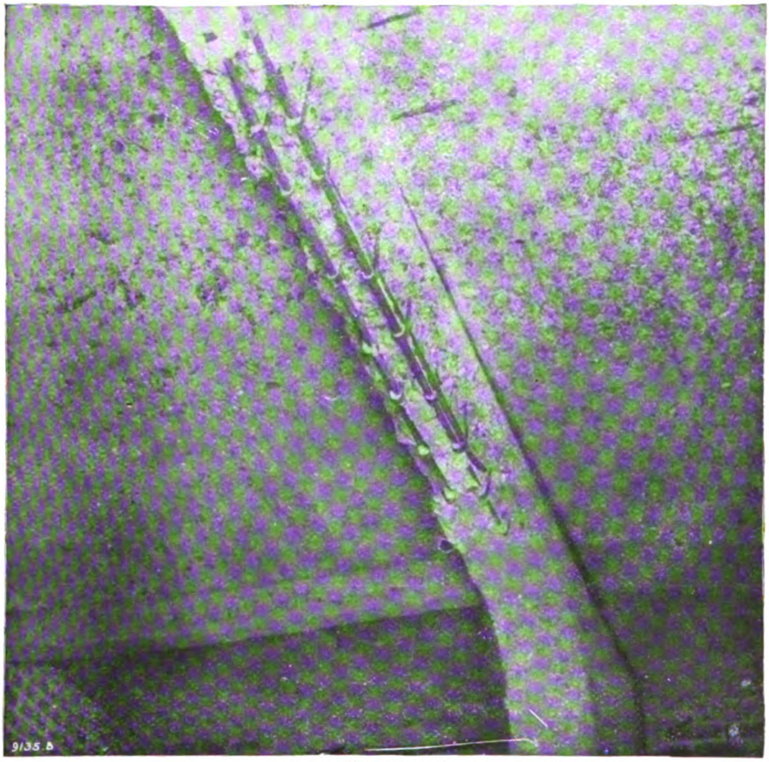
These rules for the United Kingdom have been framed with the view of giving the fullest possible encouragement consistent with reasonable safety, and require a thickness of protecting concrete, prepared with Portland cement and aggregates described, in front of all metal members of from one to two inches, governed by the sectional area of the metal to be protected.

The recommendations of the American National Board of Fire Underwriters provide that such thickness of concrete shall be from one to four inches, but allow a somewhat wider range of concrete aggregates, and a much larger area for the building.

It is possible that, with further experience, both sets of rules may need elaboration to meet requirements for buildings varying in extent and occupancy.

DIFFERENTIATION BETWEEN ORDINARY AND WAREHOUSE BUILDINGS.

Office or domestic buildings, and buildings of moderate size containing a limited amount of combustible material, if constructed with reinforced concrete, may not require equal thickness of protecting concrete to that absolutely necessary for large factory and other buildings containing merchandise or large quantities of combustible goods, the burning of which would result in great and continued heat. For buildings of this class ample protection for all steel members, with suitable concrete, must be provided if fire-resisting qualities are desired.



From "Engineering."

FIG. 6. A HENNEBIQUE FLOOR AFTER NEW YORK (C.U.) FIRE TEST,

Floor on the Hennebique system, tested at the Columbia University Fire Testing Station, on July 20th, 1904, comprising two bays of 6 ft. span by 14 ft., supported by beams of 11 ft. 7½ in. span, one of which beams had an intermediate support (see page opposite). The maximum deflection at any one point was $2\frac{13}{16}$ in. The load during the test was 150 lbs. per ft. super. The duration of fire was 4 hours and ranged over 1800° Fahr. The fire was followed by the application of water.

The thickness and composition of concrete needed for the satisfactory protection of steel members in reinforced concrete when under full load, especially as regards vertical supports, has not been conclusively determined, but sufficient is known of the action under fire and water of concrete prepared with gravel or Thames ballast aggregates as usually employed, to allow of the definite statement that such concrete is not fire-resisting, as the flints and dense pebbles of which gravel is chiefly composed split and break up the concrete under the high temperatures frequently reached during serious fires, in addition to which the dehydration of concrete made with these dense aggregates apparently proceeds quicker than is the case with aggregates of a more porous nature.

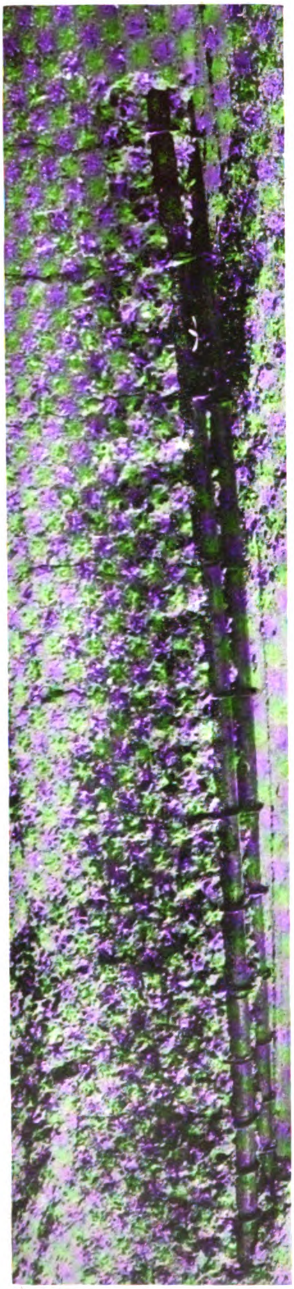


Fig. 7. A Beam in the Coignet Floor—after London (B.F.P.C.) Fire Test (The First Test).

It is to be feared that many large and important warehouses recently erected with gravel concrete, having very slight protection for steel members in beams and columns will fail under the test of a serious fire amongst the goods warehoused. In some cases the fire-resistance of columns has been seriously weakened by heavy angle irons lugged into the concrete flush with its surface, as these angles would twist under the action of fire and break up the concrete. Any metal or other material required for mechanical protection should not be fixed into the concrete.

The failure during fire of one or more beams or columns in extensive lofty warehouses fully loaded, constructed throughout with reinforced concrete, would involve very heavy loss on the buildings in addition to the destruction of their contents. The monolithic character of the construction may prevent total collapse, but considerable displacement would be inevitable, and the removal of any defective portions could not fail to be a long and costly operation. This alone suggests the necessity for providing adequate protection for all metal rods or bars against fire, heat and water.

FIRE TESTS WITH REINFORCED CONCRETE.

Reports of various specialists' private or "show" tests, until recently chiefly relied upon, are very incomplete and occasionally quite incorrect. They lacked independent supervision and the *bona fides*. They also did not give particulars of the cement aggregates used in the concrete, nor the diameter of the steel rods, nor the thickness of their protecting concrete. When some of these particulars are given no reference is made to the load, although any tests during which floors, girders, and stanchions are not subject to a full load are manifestly misleading.

There have so far also, scarcely been any cases of serious fires in reinforced concrete buildings to go upon. Some of the examples presented by specialists, it must be added, have upon enquiry been found quite unsuitable "object lessons," the fires either being trivial or, as can be shown in one notable case, actually non-existent.

The Fidelity and Guaranty Building at Baltimore, constructed on the Hennebique system by the Baltimore Ferro-Concrete Co., so frequently referred to, was an office building, and forms no reliable guide as

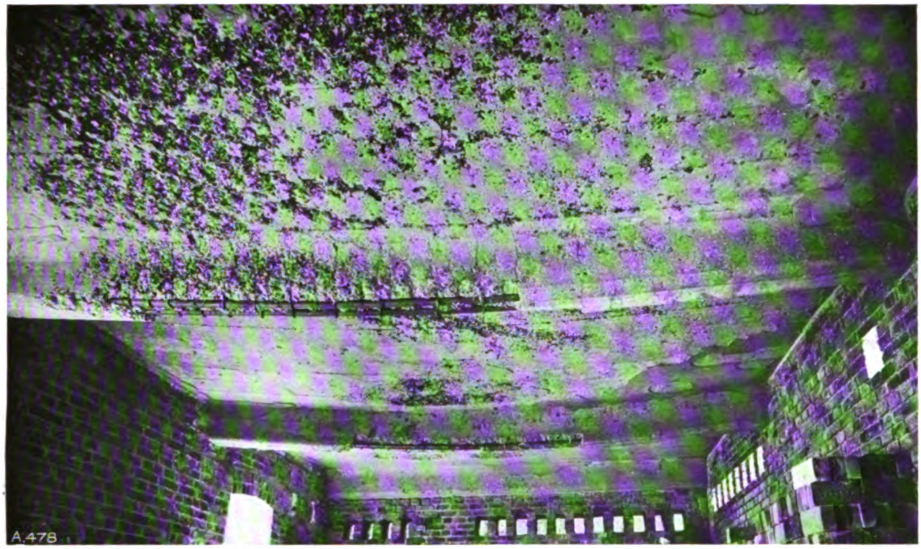

A.478

FIG. 8. A COIGNET FLOOR AFTER LONDON (B.F.P.C.) FIRE TEST. (FIRST TEST.)

Floor on the Coignet system, tested at the British Fire Prevention Committee's Testing Station on October 25th, 1905, comprising 3 bays of 6 ft. 9 in. span by 15 ft., supported by beams of 15 ft. span. The maximum deflection was $5\frac{9}{16}$ in. The load during fire was 280 lb. per square foot. The duration of fire was 3 hours up to temperatures ranging over 1,800° Fahr. The fire was followed by the application of water for 5 minutes.

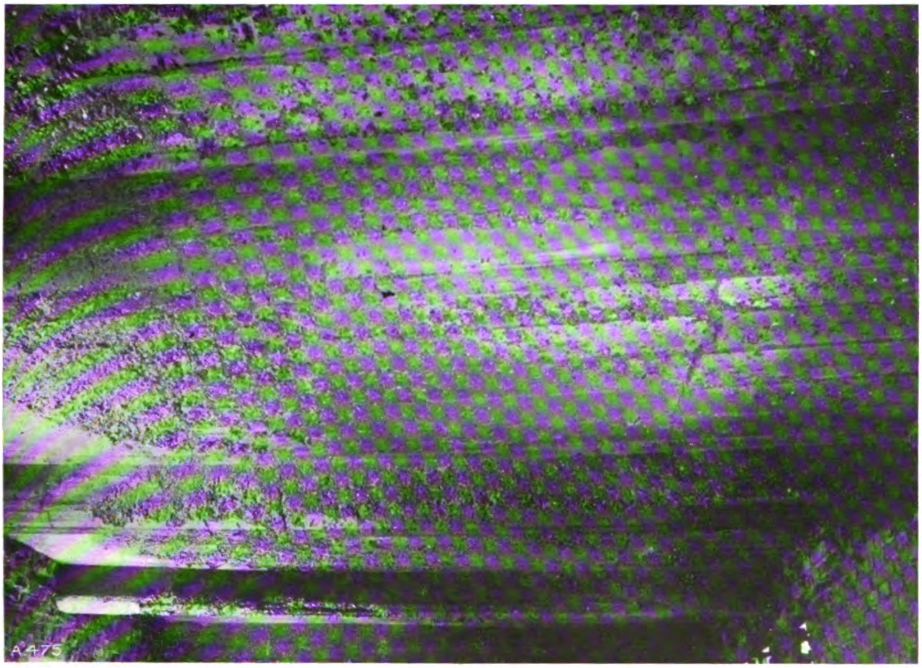

A.475

FIG. 9. A COIGNET FLOOR AFTER LONDON (B.F.P.C.) FIRE TEST. (SECOND TEST.)

A second floor on the Coignet system, tested at the British Fire Prevention Committee's Testing Station on May 22nd, 1906, comprising 3 bays of 5 ft. span by 15 ft. supported by beam of 15 ft. span. The maximum deflection was $4\frac{3}{16}$ in. The load during fire was 280 lb. per square foot. Duration of fire 4 hours up to a temperature of 1,800° Fahr. followed by the application of water for 5 minutes.

to the effect of fire on a large undivided warehouse having its floors heavily stocked with combustible merchandise and other goods.

The Antwerp petroleum fire of 1903, frequently mentioned as an instance where reinforced concrete saved the city from a conflagration, occurred some miles outside the city in question. An example of a fire near Frankfort also sometimes named as an example is (according to the public authority concerned) an instance of the efficiency of the behaviour of reinforced concrete under explosion shock rather than under fire, the fire having been trivial. Other unsuitable "object lessons" could be quoted.

Experienced fire engineers who examined all the "fire-proof" buildings at Baltimore shortly after the conflagration have stated that, in their opinion, if the "fireproof" office buildings had been stocked with combustible merchandise, by the burning of which the structure would have been subjected to great heat for a longer period, they would all have collapsed, including the reinforced concrete buildings. As to experience at the San Francisco conflagration, I would only refer to Captain Sewell's excellent article in No. 4 issue of this journal to indicate that, whilst some valuable lessons as to the general superiority of concrete construction were obtained, there were no conclusive examples of reinforced concrete as put up in ordinary building practice proving anything remarkable.

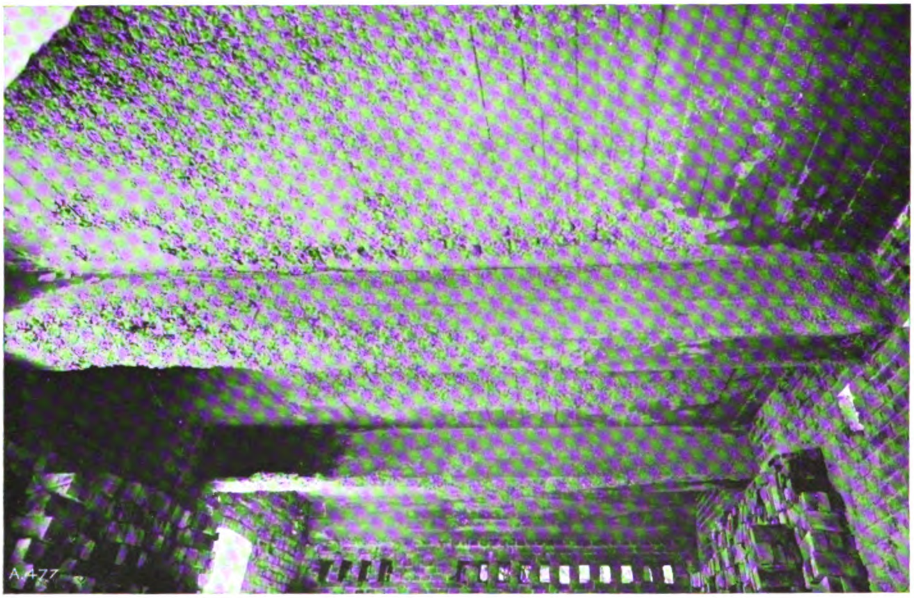


FIG. 10. A FLOOR ON THE "INDENTED BAR" SYSTEM AFTER LONDON (B.F.P.C.) FIRE TEST.

A floor on the "Indented Bar" system, tested at the British Fire Prevention Committee's Testing Station on July 25th, 1906, comprising 3 bays, one 6ft. 3in. span, and two of 6ft. 10in. span by 15ft., supported by beams of 15ft. span. The maximum deflection was $\frac{9}{16}$in. The load during fire was 280 lbs. per square foot. The duration of fire was 4 hours up to a temperature of over 1750° Fah. The fire was followed by the application of water for 5 minutes.

A test made at Chicago in August last by a manufacturing company shows that reinforced concrete columns without special fire protection, after being subjected to fire for three hours at an average temperature of 1,500 deg. Fahr., and then allowed to cool for an hour, lost 72 per cent. of their original strength. The strength of these columns when hot was probably nil.

OFFICIAL TESTS.

Tests conducted by the British Fire Prevention Committee, however, now offer thoroughly reliable evidence of the behaviour of reinforced concrete when subjected to fire. One of the earliest of these tests was that with a Visintini floor, formed with lattice concrete beams placed close together. The concrete used was composed of Portland cement and sand in the proportion of 1 to 3, reinforced with steel rods $\frac{3}{16}$ in. and $\frac{5}{16}$ in. diameter, the thickness of the concrete outside these rods being about 1 in. The floor was 10 ft. by 10 ft., loaded to 224 lb. per foot super. This floor collapsed under a maximum temperature of 1,940 deg. Fahr., reached in 107 minutes—*i.e.*, collapsed in under 2 hours. (See *Figs.* 1 to 4.)

Other tests have been made with floors constructed on the "Coignet" system, "Indented Bar" system, "Herbst" system, etc., and also with "Expanded Metal" as a reinforcement. In each case good concrete was used, and only where its thickness in front of metal rods was less than 2 in. was the metal more or less exposed, and did deflection occur.

One of the most interesting features of these reliable tests was the result of the Coignet second test after the mistake of insufficient protection had been realised in their first test (see *Figs.* 7 to 9). The tests with steel and concrete floors undertaken by the Committee have also, of course, a bearing upon this question of reinforced concrete. The early tests with the Columbian floor in 1899 and latterly two tests on a skeleton floor (see No. 2 issue, page 141) proved valuable object lessons.

Illustrations taken from the Committee's official reports, showing the results of some of these tests, are given with some data.

At some independent laboratory tests made by the Fire Protection Association of the United States at Chicago in May, 1905, concrete beams 6 ft. long, 8 in. by 11½ in., having ¾ in. steel rods embedded therein, were subjected to high temperatures in a low brick furnace heated by natural gas consumed in two 3-in. Bunsen burners, a Le Chatelier pyrometer being used to measure temperatures. The concrete was made with high-grade Portland cement one part, sand two parts, coarse screened gravel three parts by volume. The results were as follows:—

> Where the thickness of concrete in front of a rod was 1 in., it was found that the rod acquired a temperature of 770 deg. Fahr., reducing its strength 50 per cent., when the furnace under the beam showed a temperature of 1,750 deg. Fahr., which was reached in 110 minutes. With similar concrete having a thickness of 2 in. in front of a rod, the temperature of the rod was 650 deg. Fahr. when that of the furnace was 1,870 deg. Fahr., reached in 142 minutes; with 3 in. of concrete in front of a rod, its temperature was 600 deg. with a furnace temperature of 1,895 deg. Fahr., reached in 154 minutes With concrete having similar aggregates, but a much smaller proportion of cement, say 1 to 7 in place of 1 to 3, the results were less favourable. In one case the rod had a temperature of 700 deg. Fahr. with a furnace temperature of 1,320 deg. Fahr., which was reached in 50 minutes. Concrete made with one part of cement, two of sand, and five of cinders proved to be a better non-conductor of heat than concrete made with aggregates of a denser character, as a rod protected with 1 in. of such concrete showed a temperature of 770 deg. Fahr. with a furnace temperature of 1,910 deg. Fahr., reached in 120 minutes. With a thickness of 3 in. the rod showed a temperature of 400 deg. Fahr. with a furnace temperature of 2,000 deg. Fahr., reached in 180 minutes.
>
> The longitudinal expansion of the concrete beams and of the steel rods embedded therein varied considerably, the difference being as much as ⅝ of an inch in 6 ft. in the case of concrete made with broken red granite, fully sufficient to break adhesion between the materials.
>
> The beams were not loaded, but their deflection varied from ⅛ to ¼ of an inch. A water test was not applied. After the test it was found that the concrete had lost practically all its strength to a depth of about 4 in.

These results are confirmed by some other laboratory tests made under the direction of Professor Ira H. Woolson, at the Mechanical Engineering Department of the Columbian University.

Professor Woolson, by-the-bye, has also conducted some valuable full-size tests at a station built somewhat on the lines of that of the British Fire Prevention Committee, although the equipment is less complete. The learned Professor has shown, for instance, as far back as 1904, that a floor and column built on the Hennebique system presented features quite in accord with the London experience with reinforced concrete generally. *Figs.* 5 and 6 are views published in "Engineering" of this test, and speak for themselves. With a load of only 150 lb. per ft. super, and beams of very moderate span, the floor has not yet been independently tested under British Fire Prevention Committee conditions.

LOADS AND FIRE RISKS.

The great strength of reinforced concrete admits of the concentration of heavy loads on long girders and lofty stanchions. In the case of fire in extensive warehouses heavily stocked on numerous floors this may prove a source of danger.

The weight of many classes of goods is greatly increased when saturated with water. Such increase of load over large floor spaces on each storey may be thrown on to a single stanchion at a time when it is seriously weakened by heat.

In some cases stanchions of reinforced concrete 15 ft. or 16 ft. in height are loaded up to one ton per square inch of their own sectional area, the only protection for the vertical steel rods being 1 in. thickness of concrete of doubtful fire-resisting character. Detached columns or stanchions constitute vulnerable parts of a lofty warehouse, and are liable to be put to a most severe test by fire burning amongst goods stored around them.

Fire tests of reinforced concrete stanchions under a full load do not appear to have been made up to the present, but tests of this material in floors and beams show that for the protection against fire of steel rods 1 in. or more in diameter, Portland cement concrete (prepared with broken brick clinkers, or similar aggregate and sand) at least 2 in. thick in front of the rods at every point is necessary. For important members, such as stanchions and beams, it would only be prudent to provide 3 in. of concrete protection, especially in large buildings, for warehousing merchandise.

DEHYDRATION OF CONCRETE.

It should be borne in mind that the water of crystallisation in the Portland cement contained in the concrete is slowly driven off by heat, and the strength of the concrete thus affected is destroyed. This weakening process continues as long as the heat is maintained, and an ample margin of concrete beyond that required for structural purposes is, therefore, necessary to avoid collapse.

A full proportion of cement should also be used to obtain a large amount of crystallisation, by which the weakening process is delayed.

CONCLUSION.

Although reinforced concrete forms an excellent material for the construction of fire-resisting buildings, it unfortunately admits of the use of unsuitable materials and workmanship and of insufficient protection for metal near the outer face of the concrete. It is, therefore, all the more necessary for architects, engineers, and especially owners and intending occupiers, to be on their guard against such practices which amount to spoiling the ship for a ha'porth of tar.

Conditions applicable to reinforced concrete, requiring special attention to secure satisfactory resistance to fire, may be summarised as follows:—

1. Concrete having aggregates consisting of hard, porous brick, broken so that the whole will pass a ¾-in. mesh, all dirt being screened out and replaced

with a due proportion of sharp sand, offers the greatest resistance to fire; while concrete made with dense aggregates splits and breaks up when subjected to fire.

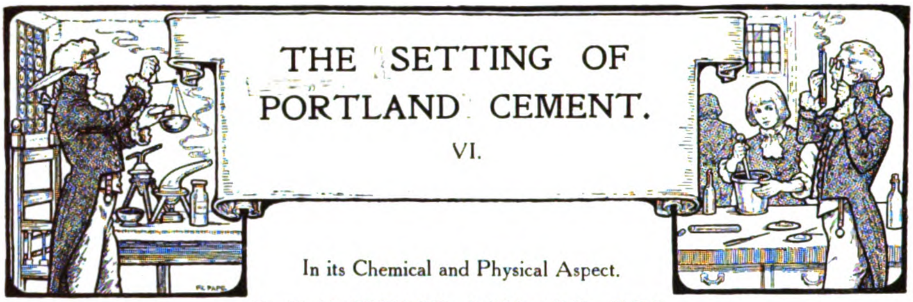
2. Dehydration, by which the strength of concrete is slowly destroyed, commences at a temperature of about 600 deg. Fahr. It is, therefore, necessary to provide ample thickness of concrete beyond that needed for load carrying purposes. Such thickness should not be less than 2 in., with 3 in. for the more important columns and beams. This additional concrete will also serve to prevent undue heat reaching the metal reinforcement.
3. Heat striking metal reinforcement at any point will be conducted through its whole length, while the concrete, being a slow conductor, may remain cool at points where the enclosed metal is hot. This may lead to dangerous internal strains, and it is, therefore, important that every part of the metal be amply protected against heat.

The best results, both as to strength and resistance to fire, will probably be obtained by treating these requirements separately, using concrete with aggregates that will give the greatest strength, encased with a due thickness of fire-resisting concrete made as above described, or with porous terra-cotta 3 in. thick.

In all cases the use of a full proportion of artificial Portland cement of the highest quality is essential.

For work in Great Britain it would also be well to demand that any reinforced concrete system to be employed shall have obtained classification of " fully protective " (Class B) under the Fire Prevention Committee's standards on a full-size floor section of 200 to 300 ft. super. A four-hour fire test at 1,800 to 2,000 deg. Fahr. whilst under load of 2½ cwts. per lb. super. and followed by water will demonstrate the strong or weak points alike. For work to have passed such a test with but small deflection is a safeguard for the building owner, the underwriter and the professional adviser alike.

It will be a public calamity if, in the general application of reinforced concrete, for the construction of fire resisting warehouses, cement and aggregates unsuitable for the purpose are used, or insufficient thickness of concrete for the protection of all steelwork provided. Buildings erected on such lines will collapse when subjected to fire and seriously discredit all reinforced concrete structures.



THE SETTING OF PORTLAND CEMENT.

VI.

In its Chemical and Physical Aspect.

By **D. B. BUTLER, A.M.Inst.C.E., F.C.S.**

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier articles has encouraged us to extend our list of contributors on this subject to the leading authorities of other countries. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.

This very important subject, on which we have been able to put forward the opinions of many eminent and experienced writers, is, of course, yet a question in which finality has not been reached. The Setting Time of Cement seems to vary from innumerable causes—the same cement being, under some circumstances, QUICK setting, and under others SLOW setting. The difficulty of arriving at any method of rendering a cement of uniform setting property under all conditions, seems to be almost insurmountable, and this would appear to be only what is to be expected, seeing that cement is a chemical compound which, to be of any use, must be in a condition to change its chemical and physical character upon the addition of water, and an article such as this must always be liable to change in its characteristics during storage, in accordance with varying climatic and thermometric conditions. In view of what has been written as to the danger of using gypsum for regulating the setting time of cement, it would seem that a distinct advance has been made by the introduction of the steaming or hydrating process described by the author, which process is conducted under a patented method, generally associated with the name of Mr. H. K. G. Bamber, F.C.S. Cement thus treated during manufacture should be much less likely to change from the causes mentioned.—ED.

As is now fairly generally recognised, the active ingredients of Portland cement are silicates and aluminates of lime, most usually formed by the heating together to incipient fusion point, an intimate mixture of carbonate of lime, in the form of limestone or chalk, and silicate of alumina, in the form of shale or clay. The exact form in which these silicates and aluminates exist in the cement is, in the writer's opinion, still open to some question; practice has shown that the greater the lime content, compatible with soundness, the better and stronger the cement, and the synthetical researches of Newberry suggest that the highest lime compounds that may be considered sound, or constant in volume, are tricalcic silicate and dicalcic aluminate. Lime, silica, and alumina are the main ingredients of Portland cement, and generally form about 96 per cent. of the total; the remaining impurities have practically no cementitious value, and likewise no appreciable effect upon the setting properties of the material, with the exception of water and sulphuric acid, which will be dealt with later.

The setting of cement, when mixed with water, is the result of solution, the water dissolving certain parts of the powder until first saturation and then supersaturation results; immediately supersaturation is reached, crystals are deposited around suitable nuclei, and the water thus set free again becomes supersaturated, and again deposits crystals; thus the process goes on until the whole available space between the undissolved particles is a solid mass of crystals, and the cement is then set. Whether a cement is quick or slow-setting depends primarily upon its chemical composition, a highly aluminous cement, *ceteris paribus,* being quicker-setting than one low in alumina, owing to the alumina compounds being more soluble than the silicates. But, apart from its chemical composition, there are so many other controlling factors which govern the setting time that it is impossible to judge of the properties of a sample from its analysis alone. In the first place, the mechanical mixture of the chalk and clay in the first part of the process of manufacture may have been imperfectly performed, in which case the alumina, though present, will not be evenly distributed throughout the mass; in the second place, the calcination in the subsequent part of the process of manufacture may have been imperfectly performed—either insufficiently, in which case, although the ultimate analysis of the compound may be the same, its constituents would not be properly combined; or on the other hand the calcination may have been excessive, and the material reduced more or less to the condition of molten slag, which would practically destroy its setting properties. In the third place, the setting of cement depends very largely upon the fineness to which it is ground. Seeing that the setting process is a process of solution and supersaturation, it is obvious that the finer and more pulverulent the material, the more readily is it acted upon and dissolved by water, and consequently the more rapid does the setting become. It will, therefore, be seen that raw materials having exactly the same composition may be made to produce a cement varying in setting properties according to the manner in which the method of manufacture is varied. The effect of the fineness of the powder upon setting properties has only been appreciated of late years, since the English manufacturer began to find himself being ousted from foreign and Colonial markets by his Continental rivals, who supplied a finer ground material, having a correspondingly higher cementitious value. It was then found that a cement which up to a few years ago was considered well ground—*i.e.*, leaving about 10 per cent. on a No. 50 x 50 sieve, and at that degree of fineness possessing comfortable setting properties—was rendered very uncomfortably quick-setting by being reduced to a more modern degree of fineness. The result was that, in order to render the cement reasonably slow-setting, methods of artificially governing the setting time had to be adopted, and following the Continental custom, this generally consisted in the addition of small percentages of gypsum, ranging from ½ to 2 per cent., ground up with the cement in the final process of manufacture. As a fair average example of the effect of fineness upon setting properties, a cement which when ground to 22 per cent. of residue on a No. 180 sieve, had an initial set of 25 minutes and was set hard in 45 minutes, when reground so as to all practically pass a No. 180 sieve, commenced to set in 1 minute and was set hard in 5 minutes.

As previously stated, the method of regulating the setting properties generally adopted was imported from the Continent, and consisted of the addition of gypsum. According to researches by Candlot, the efficacy of this regulating agent depends upon the presence of a small quantity of free lime in the cement. He has ascertained that the addition of gypsum to the cement results in the formation of a salt which he identified as sulpho-aluminate of lime. Aluminate of lime being insoluble in a saturated solution of lime, his theory is that "if sulphate of lime and free lime are present, together with aluminate of lime, it follows that the combination of the sulphate of lime with the aluminate can take place, but very slowly, because the aluminate cannot become hydrated on account of the immediate solution of the lime." His experiments show that a cement made slow-setting by the addition of 1 per cent. of gypsum becomes extremely quick-setting when the water used for gauging contains 2 grammes per litre of carbonate of soda, which converts the free lime into carbonate of lime. Conversely, a cement which was made slow-setting by gypsum, and had become quick-setting again after several days aeration, and the presumptive conversion of the lime into carbonate, is made very slow-setting by the addition of 2 per cent. of quicklime.

The author disagrees entirely with M. Candlot as to all cement containing a little free lime. Free lime is a term usually employed to denote the disruptive agent which causes unsound cement to expand and blow, but it is altogether a misnomer. The more correct term for this disruptive agent is "unstable lime compound," being a compound which hydrates so very slowly that it is frequently weeks or even years before it is fully hydrated, and then with immense increase of volume. At the temperature to which it is subjected in a cement kiln, free lime cannot exist in a cement compound, and only those who have experienced the readiness with which lime compounds, very rich in lime, become contaminated by and combine with the fireclay of the furnace at high temperatures, can appreciate the force of the asseveration that free lime cannot exist in cement compounds under the ordinary conditions of manufacture.

It is now a well recognised fact that during the setting of Portland cement a part of the lime is deposited as calcic hydrate; it is also well known that cement will not absorb carbonic acid unless in the presence of moisture, by which it is first hydrated. The inference, therefore, is that the free lime described by M. Candlot as existing in a cement, and being necessary for the action of the gypsum, is lime which is set free by hydration by the water in the atmosphere. The absence of this free lime (or rather liberated crystals of calcic hydrate) is probably the reason why additions of gypsum frequently have no effect upon clinker produced by rotary kilns, unless the clinker is watered in the cooling process—*i.e.*, there is no calcic hydrate present for ready solution and prevention of the solubility of the aluminate of lime, with consequent retardation of setting. The writer has proved this more than once when making cement in a small experimental way in his gas furnace; the clinker, on grinding, produced an extremely quick-setting cement, upon which the addition of 1 or 2 per cent. of gypsum had not the slightest effect, probably owing to its extremely dry and well-burnt condition, and the consequent absence of calcic hydrate. Clinker produced by the less modern intermittent vertical kiln generally contains more or less imperfectly burned material, which more readily hydrates and forms calcic hydrate; hence the clinker is more suitable for the regulation of setting by the addition of gypsum than that produced by the rotary type, in which the degree of calcination being thoroughly under control generally produces a very well and evenly burned product. Cement produced by rotary kilns, before its setting time is artificially regulated, is as a rule much quicker-setting than that produced by the vertical intermittent chamber kiln, and it will be found that the former generally contains only about one-half of the sulphuric anhydride contained by the latter, although made from exactly the same raw materials. The reason probably is that in the intermittent chamber kiln the sulphur compounds volatilise in the process of burning, and, being cooled on passing through the drying chamber wherein the next charge of raw mixture is being dried by the waste heat from the kiln, are deposited therein and loaded into the kiln with the next charge. With the rotary kiln, on the other hand, the volatile compounds are not cooled sufficiently for deposition until they reach the chimney shaft, too late, of course, for their deposition to affect the raw material passing into the kiln.

The only other agent in general use for regulating the setting properties of cement is water, which is usually applied in the form of steam; it is, however, also used in the liquid form, sprayed on to the hot clinker as it leaves the kiln, which serves the double purpose of assisting to cool the clinker before it is conveyed to the grinding mills and of retarding the setting of the cement produced therefrom. When used as steam, it is most generally applied during or after the final pulverisation process, the former being by far the most successful; by one patent process the injection of steam into the grinding mill is so arranged that the setting time can be adjusted to any desired degree by the admission of steam of 5 to 25 lbs. pressure, according to the degree of slowness required. The patentees claim, with some show of justice, that by admitting steam within the grinding machine in this way during the final pulverisation process the same results are effected as by spreading the cement abroad in the usual way to mature. At any rate, the amount of steam admitted is thoroughly absorbed by the cement, for the air at the mouth of the machine at which the cement is discharged is perfectly dry.

Of the two methods of regulating setting, the use of water is certainly preferable to the use of gypsum, for apart from the retarding effect of the latter being apparently evanescent, and of no avail after a more or less short period, the writer's opinion is that its ultimate effect upon the stability of the cement has as yet by no means been thoroughly thrashed out; whereas water, on the other hand, can only be a negative or passive evil. The use of water also has this advantage, that if the cement should contain any of the before-mentioned disruptive agents, in the form of unstable lime compounds, there is the possibility, nay even probability, of their being hydrated and rendered innocuous by the water; whereas the addition of gypsum has no such beneficial effect; in fact, the presence of any excess of gypsum, say 3 or 4 per cent., has been found to result in very serious consequences.

It is well known that if cement is worked or manipulated after setting has commenced, its strength is thereby materially impaired, if not absolutely ruined. The reason is that the crystals, which are deposited and have already begun to interlock, are broken up and their interlocking or bond destroyed; the extent of the damage will, of course, depend on how far the setting or interlocking has proceeded before the breaking up and destruction of the bond takes place. This applies more particularly to quick-setting cement, which commences to stiffen very rapidly, and is not of such importance with the slow-setting varieties; in fact, experiments made by the writer some twenty years ago for his predecessor, the late Henry Faija, went to show that some slow-setting cements are improved, at all events within the ordinary dates of testing, by being allowed to partially set, and then being beaten up again and filled into the moulds. This point was particularly raised during the Aberdeen Harbour failures some twenty years ago, when the engineer in charge of the work described the use of what was termed "plastic" concrete—*i.e.*, concrete which was allowed to partially set, and then worked up and made plastic before being placed in the skips for deposition under water. The advantage claimed for this process for work under water was, that by allowing the concrete to partially set beforehand, there was less likelihood of the cement being separated from the aggregate on deposition under water; but since, in order to obtain good results, everything depended upon the breaking up and re-manipulation of the mass being done at the exact moment when it could be made plastic without the addition of further water, there was considerable danger, in dealing with large masses of material on a work of considerable size, that the narrow limits of time permissible would be either exceeded or not reached, with correspondingly inferior results. In the writer's opinion all such tampering with the setting of a somewhat delicate material, such as cement, should be rigorously avoided, since the benefits to be derived are by no means commensurate with the risks run.

A chemical aspect of the setting of cement is that, in common with many chemical reactions, it gives rise to the evolution of heat, in direct ratio to the rapidity with which the crystallisation proceeds—*i.e.*, rapid crystallisation gives rise to considerable heat, whereas with slow crystallisation the evolution of heat is scarcely noticeable; in other words, although the same amount of heat is generated in the end, with rapid crystallisation it is sufficient to cause considerable rise of temperature, whereas with slow crystallisation, the heat radiates as fast as it is generated and does not affect the thermometer. This obvious fact has in the past given rise to considerable trouble, due to the false deduction that evolution of heat must necessarily denote the presence of free lime and the heat due to its hydration; many quick-setting cements, perfectly sound and satisfactory in every way except that the crystallisation was rather rapid, have been condemned on that account as unsound and unfit for use; on the other hand, it has been proved that not only does the evolution of heat during setting not prove unsoundness, or the presence of free lime, but, what is more to the point, so far as this particular test is concerned, a sample may be slow-setting, and, therefore, show little or no rise of temperature during setting, and at the same time be utterly unsound and worthless. It is to be hoped that the publicity which was given to the matter a short time ago has effectually given this wrong-headed notion its final quietus.

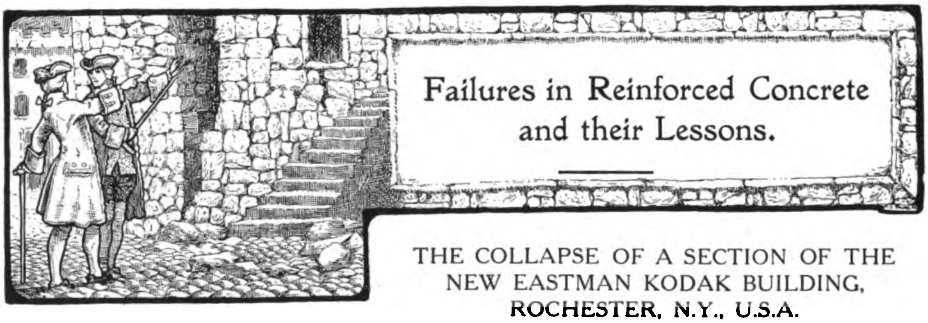
A chemical aspect of the setting of cement, which even yet is scarcely appreciated at its proper value, is that, like most chemical reactions, it is accelerated by heat and retarded by cold. Instances are frequently coming to the writer's notice in which difficulties have arisen through ignorance of this very obvious fact. Given a rather unusually slow-setting cement, a few days very cold wet weather, with an atmospheric temperature only one or two degrees above freezing point, and the concrete user is annoyed and surprised to find that he cannot strike his centering, etc., as soon as he is accustomed to do in warmer weather; or perhaps he does strike it at the usual time with disastrous results. Experiments have shown that the setting time of cement is almost twice as prolonged at 40° as it is at 60°, more especially with the slower-setting varieties; but it is to be feared that users of cement who are aware of this primary fact are still very largely in the minority. With the quicker-setting cements it is probable that the heat evolved during crystallisation still further accelerates the setting, by perceptibily raising the temperature of the mass.

Another aspect of the setting of cement which is partly physical and partly chemical, but which relates more particularly to the testing laboratory, is that a very slow-setting cement left in the open air will frequently develop shrinkage cracks, due to the evaporation of the water before sufficient crystallisation has taken place to form interlocking, and thus prevent the parting of the mass. These cracks, which are generally in the centre of the pat and do not extend to the edges, are analogous to the shrinkage and cracking of clay when too rapidly and unequally dried, and may be altogether prevented by covering with a damp cloth, or otherwise preventing the evaporation of the water, until the mass has sufficiently set to withstand such shrinkage. A peculiar instance of this shrinkage, of a unique and interesting nature, occurred in the writer's testing-room a short time ago. Briquettes made of an extremely slow-setting and extraordinarily finely-ground cement were found to have shrunk away slightly from the edge of the mould within a few hours after being made, and on removal from the mould, after the usual 24 hours period, many of them were found to be cracked and divided in two at the point of smallest section. This result was evidently due to the shrinkage of the material setting up tensional stresses against the sides of the mould, resulting in the fracture of the mass at the weakest point, since when the briquettes were kept covered with a wet cloth and removed from the mould within 7 or 8 hours of gauging, these cracks were no longer produced.

Moreover, the crack was not visible on the top skin or trowelled surface; but on the under side of the briquette, before being removed from the mould, it was plainly seen extending across the sectional area of the briquette.

From a user's and practical point of view, the cement with the most convenient type of setting property, is that which is sufficiently slow in its initial stages to permit of the material being properly worked and manipulated and left at rest before stiffening commences; and then, when the material is once in position and at rest, the quicker the hardening proceeds the better, thus enabling centres to be struck, and the work to be proceeded with as rapidly as possible. So far as regards the estimation of setting properties, the determination of the " initial " set or period of stiffening is, as a rule, quite as important as the determination of what is known as " final " or " hard " set, which is merely an arbitrary term denoting the period when the mass is able to bear without indentation a flat pointed needle of a certain diameter and of certain weight; yet many specifications, notably the recently issued British Standard Specification, omit the initial set altogether. Surely it is as important to know how long a cement may be worked without risk of " killing," or breaking up the already interlocked crystals, as to know when it has attained an arbitrary degree of hardness. And yet cements are condemned as too quick-setting because the " final " set is, say, 3 hours instead of 4, no regard whatever being paid to the fact that the initial set is in all probability quite equal to all ordinary requirements. As before stated, the only manner in which a cement can be too quick-setting, is when the intial set is too quick for proper and convenient use, and if this is satisfactory, the hard set cannot follow too quickly.

In conclusion, the writer would crave his readers' indulgence for this somewhat discursive essay, in which he has endeavoured to place before them in a plain, matter of fact manner, some of the salient features of the setting and hardening of cement; he has not attempted to enter into the many abstruse theories as to the why and wherefore of the subject, these theories and opinions being of so divergent a nature that their discussion would be as unprofitable as it was wearisome. There is a vast field for research on this subject, and only those who have devoted much time and study to it, can fully appreciate how much of it is mere theory and how little, how very little, is indisputable fact.



Failures in Reinforced Concrete and their Lessons.

THE COLLAPSE OF A SECTION OF THE NEW EASTMAN KODAK BUILDING, ROCHESTER, N.Y., U.S.A.

The following article on the collapse of a reinforced concrete building at Rochester, U.S.A. is presented after applying for particulars to the Coroner, who directed the enquiry into this failure, which involved loss of life. We received a copy of the Coroner's verdict, and were officially referred to the "Engineering News" of January 3rd, 1907, as containing a reliable summary of the matter. By courtesy of that journal we also present some illustrations from photographs kindly provided by them.

We are given officially to understand that Messrs. William Costello, foreman for the contractor, and Perley S. Wilcox, assistant manager to the owners of the building, both referred to in the Coroner's verdict, are awaiting trial for criminal negligence.

Our enquiries at Rochester, U.S.A., having come to the notice of the building owners, they have favoured us with an explanatory letter, and a report by two experts engaged by them to report on the failure. We publish a summary of the letter, and the report in full.

We refer to this article at considerable length in our Editorial columns, but would here repeat that we view the failure as due to the negligence in course of construction of parties whose responsibility has yet to be fixed, rather than to the principles underlying the design adopted.

We would also specially point out that this failure, as most failures with reinforced concrete work, occurred during the building operations, and not after final completion of the structure.—ED.

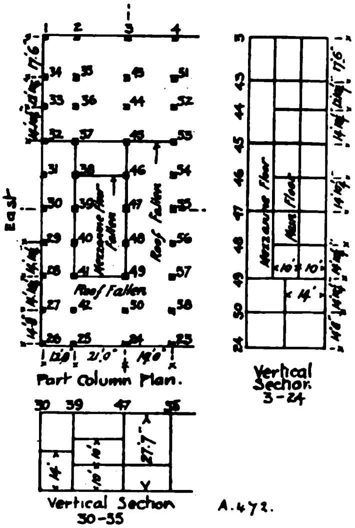


FIG. 1.

PLAN AND SECTIONS OF PART OF EMULSION BUILDING, SHOWING ARRANGEMENT OF FRAMING AND EXTENT OF FAILURE.

ON Friday, November 21st, 1906, a portion of a new building being erected at the works of the Eastman Kodak Co., Kodak Park, near Rochester, N.Y., collapsed, killing two men outright and injuring several others, two of whom died shortly afterward. The building was of the Kahn type of tile-and-reinforced-concrete construction, and was being erected by the Concrete Steel and Tile Construction Co., of Detroit, Mich., who also designed it. An investigation was instituted by Coroner Thomas A. Killip, of Monroe County, who called as expert advisers County Engineer J. Y. McClintock, M.Am.Soc.C.E., and Mr. J. Herbert Grant, M.Am.Soc.C.E., both of Rochester. Messrs. J. M. Brazill and H. Pierce, deputy fire-marshals of Rochester, assisted in the examination of the ruins. The Coroner's verdict has just been rendered, and its most important parts are printed on a following page. We are able at the same time to present a number of photographic views illustrating the wreck, together with sketches and notes taken from Mr. McClintock's technical report to the Coroner.

The eastern end of the building only was affected. *Fig.* 1, a ground plan with sections, locates the collapse more definitely. The structure has three storeys for part of its area; the main floor is 10 ft. from the ground in this part, and 14 ft. elsewhere. The total height from ground to roof is about 28 ft. All of it was of regular column, girder and slab construction, without unusually long spans. The columns, floors and roof were of reinforced concrete, floors and roof having hollow tile 12 in. wide incorporated in rows separated by concrete beams 4 in. wide, reinforced with Kahn bars. The columns were reinforced with Kahn bars and some plain round rods. The exterior walls were of brick. At the time of the collapse the framework of the building and much of the exterior brickwork was completed, and waterproofing was being put on the roof.

The extent of the collapse was as follows :—The roof and its supporting columns fell for a space about 53 ft. by 89 ft. The mezzanine floor, below, gave way over an area 21 ft. (one panel) by 45 ft. The main floor stood the shock of the falling debris without failure, except that a hole through it about 2 ft. square was made by the end of a falling girder. The view *Fig.* 2 shows that the fallen floors broke up into a general wreck-heap of tile, concrete and steel rods, though large parts of the roof remain attached to the standing part and hang down in strips. A large piece of the wreckage is seen in *Fig.* 3, showing a roof-girder (37-39) which split off from its far end and dropped bodily, breaking in two when it struck the mezzanine floor at Col. 38; the nature of the fractures in this girder is interesting.

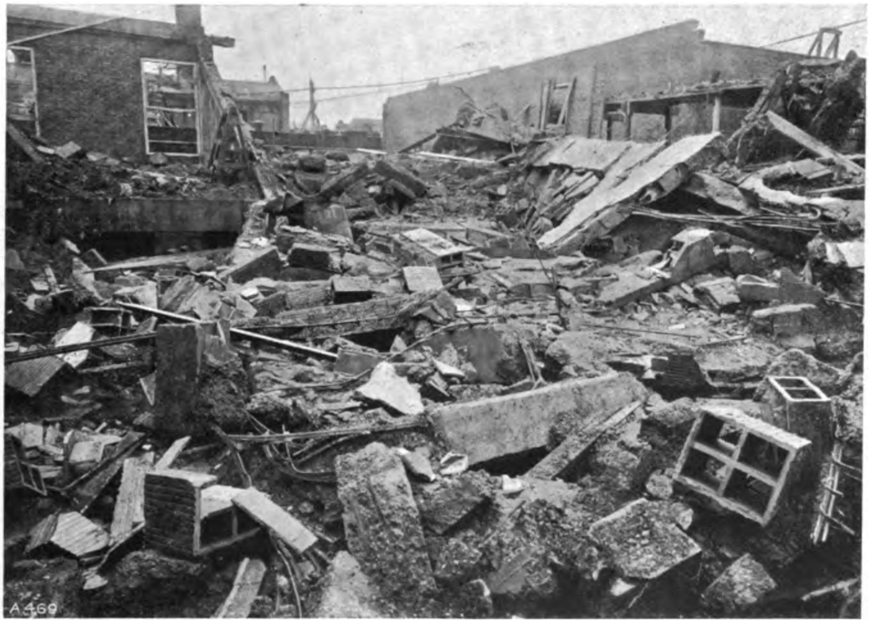


FIG. 2.

A case of a column which fell almost undamaged is Col. 30, an east wall column. The reinforcing rods at the right-hand end of this column are flush with the concrete, showing that the column had no anchorage to the floor below. The rods projecting from the left-hand end were bedded in the roof-girder, which tore away from the column. In *Fig.* 4 is a column which, though badly shattered, still has its roof-girder attached.

An examination of the ruins shows many evidences of defective workmanship and poor concrete. In the undamaged portion of the building adjoining the collapsed area, the case shown in *Fig.* 5 occurs. The lower girder, against which the ladder rests in this picture, is part of the main floor at 10 ft. above ground, while the girder above this supports the main floor at 14 ft. above ground. In the side of this upper girder is a crevice or slot some 6 ft. long, into which one can thrust the hand and feel the reinforcing bar. Evidently, in placing this bar it did not lay solid on the concrete below, and when the form was filled up the new concrete did not flow around the bar, thus leaving the long hollow space and correspondingly weakening the bond between steel and concrete. Col. 45 betrays the porous condition of the concrete in column and mezzanine floor girder, and (in the original) shows clearly that the column had been smoothed up with mortar to some extent after the forms were removed.

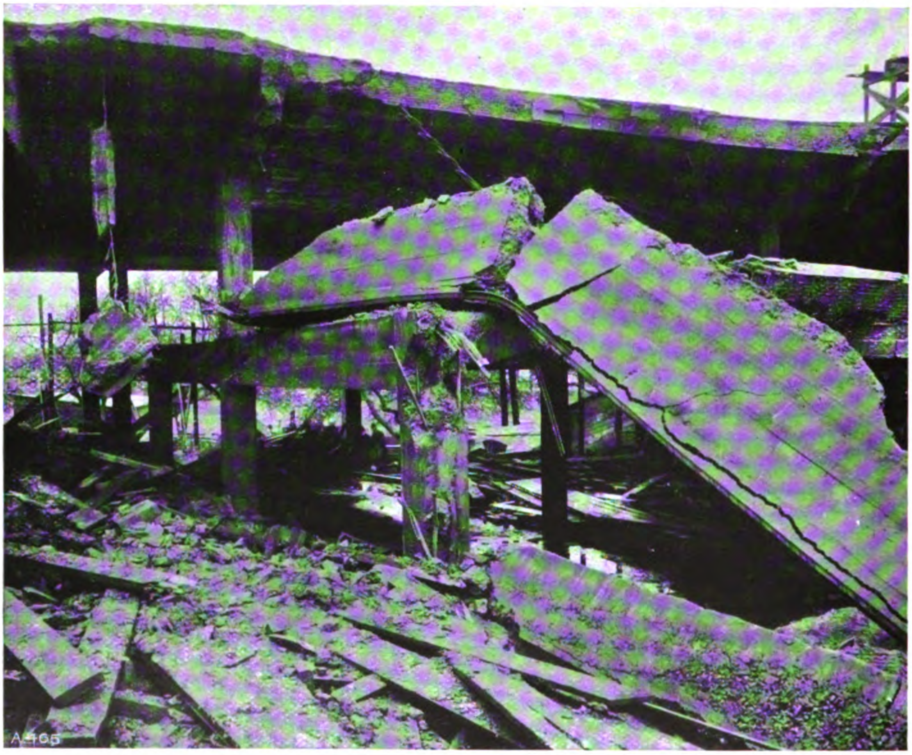


FIG. 3.

THE COUNTY ENGINEER'S REPORT.

The following is extracted from Mr. McClintock's report to the Coroner :—

Many of the posts show a horizontal joint of sawdust and shavings and paper. In Col. 2 at the level of the mezzanine floor I thrust in my knife-blade 2 in. deep. In Col. 37 at the level of the mezzanine floor there is a joint of sawdust and shavings, horizontal, nearly if not quite through the section, into which a knife-blade was thrust 2½ in. easily.

In the north face of Col. 37 (shown in

Fig. 8) there is embedded a piece of wood showing 5¾ in. wide by about 13 in. long, and probably 2 in. or 3 in. thick, set up at an angle of about 45° so as to reach clear across the face of the post, apparently dropped into the wooden form along with the shavings and sawdust before the concrete was put in above the mezzanine floor. In the same column below the mezzanine floor the concrete is so poor that I dug into it with a small stick nearly 2 in. in one spot.

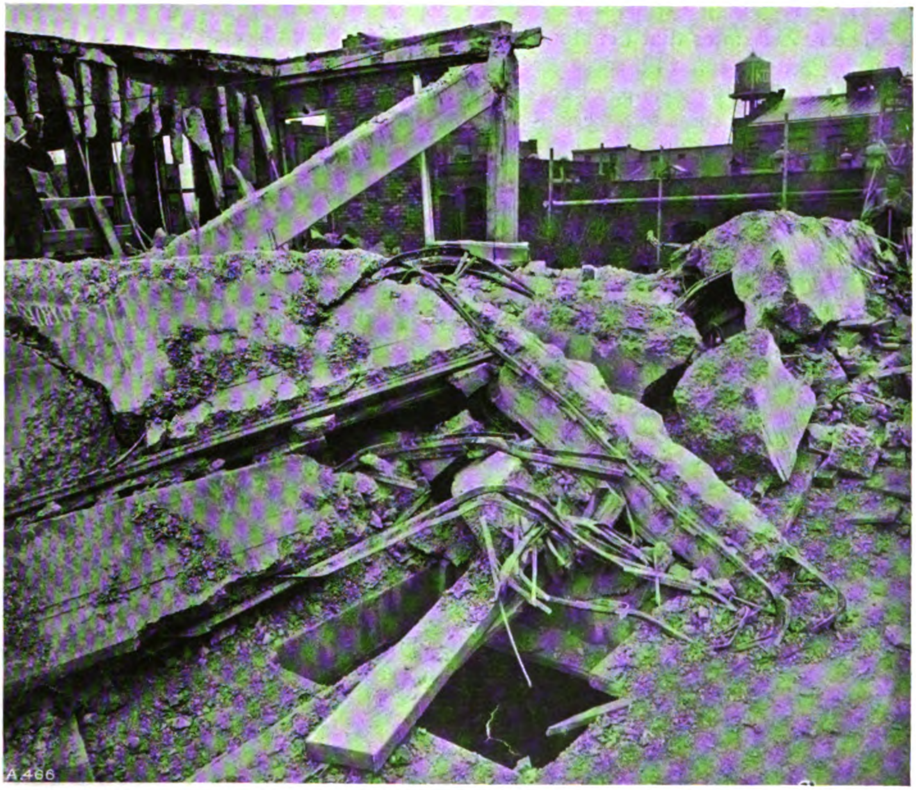


FIG. 4.

In many places the steel bars show at the surface of the girders on the side.

The girder from Col. 2 to Col. 3, although in the face of the wall, bulges out so as to be deformed, apparently due to carelessness in bracing the forms.

The fact that the main floor resisted the great shock of falling girders, posts and roof, without appreciable injury, indicates that in general the design is satisfactory. The only place broken in the main floor is where the roof-girder between columns 49 and 24, which spanned 28 ft. and sustained 560 sq. ft. of roof, slipped off from its bearing on 49 while still being held up by 24, and dropped one end 14 ft. and still stands in its leaning position, although of course the attached roof was shaken off.

The general condition of the building indicates that the cement was good and that ample time was given for setting before removal of woodwork.

In Col. 47, the upper portion, about 7 ft. long, was of such poor concrete that we easily picked off with the fingers the upper 2 ft., and could crumble most of it in the fingers. I afterwards concluded that this concrete was disintegrated by the wrenching off of the roof girder. The lower portion was pretty well covered up with debris, but appeared to have settled down in its own location by breaking. We afterwards dug down and exposed this.

I saw many places in posts and girders where the concrete was not filled with mortar, and had the open texture of a pop-corn ball, indicating that it was put into the moulds in too wet a condition.

The cinder concrete on the roof has the characteristics of earth rather than concrete.

In many cases the steel bars in girders do not connect or overlap over posts.

The fallen posts show that there was no connection of the steel bars in the part of a post above a floor and below, and there are no dowels.

The condition of the wreckage indicates almost (if not quite) with certainty that Col. 47 failed first, and below the mezzanine floor.

The report states that the stone used for making concrete appeared to be of good quality, ½-in. to 1-in., with some screenings left in; that none of the sand was left on the site, but that the sand-pile location gave every opportunity for getting dirt in with the sand, and that some of the crumbling concrete indicates dirty sand in spots.

There was no question raised as to the sufficiency of the shoring. The concrete of that part of the roof which failed was about 17 or 18 days old. The concrete of Col. 47 was about three weeks old.

The case of this column, which Mr. McClintock's report and the verdict of the Coroner charge with causing the collapse, merits further attention. The appearance of this column in the wreckage is to be seen in *Fig.* 6, looking south. The conical end in the immediate foreground of the sketch is the lowermost part of the column discoverable. Measured by the length of the protruding bars, there was about 4 ft. of column below this point, and that length of 4 ft. crushed to pieces, bending the bars up as shown.

Directly above the bar which bends up in U-shape from the conical end may be seen three short ends of steel rod projecting about 2 in. above the surface of the main floor; these are three of the four rods coming up from the column below, marking the exact location of Col. 47. The 2-in. projection apparently represents the amount of concrete eroded from the floor by the grinding action of the crushing column. Across this lower fragment of the column (at the left of the sketch) lies a part of the mezzanine floor girder which was supported by the column; it fell 8 ft. and is only 9 in. out of its original line. The girder W showing in the lower right-hand corner is the roof-girder supported by Col. 47. It fell 17 ft. and turned on its side, and is only 2 ft. out of its original line. This girder is still attached to the top part of the column, and is itself connected with the lower part of the column by four badly-crumped Kahn bars. Girder D is not shown, however, in this sketch.

The working blueprints show that Col. 47 was to be 18 x 18 in. to a point 4 ft. above the main floor, and thence 12 x 12 in.; but it was built 12 x 12 in. all the way down to the main floor. The column was designed to have four ¾-in. rods from main floor to mezzanine, and four Kahn bars from main floor to roof. But only the four Kahn bars were put in; the four round bars additional were omitted. On the other hand, the near-by column, 46, shows, on one side where it is broken away, the ends of three bars, indicating eight bars in the column, although only four are called for by the plans. It is possible that these four supernumary bars are the ones which should have gone into Col. 47.

THE QUESTION OF LOAD.

The report wherein the above observations are noted gives a computation of loads on the column in question. Summarised it is :—

Dead Load.	Lbs.
Roof	50,778
Mezzanine floor	16,227
Roof Girder W	10,500
Mezzanine Girder D ...	5,190
Column 47	1,950
	84,645

As the area of the column section was 142 sq. in., this gives a dead-load compression of 596 lb. per sq. in. But with 1·6 per cent. of steel, as in this column, and assuming $E^s \div E^c = 10$, the permissible average stress with 450 lb. per sq. in. on the concrete would be only 522 lb. per sq. in. In other words, the dead load alone exceeded the permissible load on the column as built, provided the dead load were central. If the weights of roof and floor-slabs be computed as eccentric loads,* with a mean eccentricity of 1½ in., the maximum dead-load compression is 950 lb. per sq. in. The live-load stress, with 40 lb. per sq. ft. on the roof (waterproofing and snow) and 100 lb. per sq. ft. on the mezzanine floor, computed as a central load, would be 266 lb. per sq. in. additional.

The expert report of the Coroner concludes that on account of these high stresses the design was defective; that the variations from the drawings show faulty construction; and that the weak spots in the concrete, the honeycombed character of the concrete in the lower part of many columns, and the presence of leaves, sawdust, shavings and large blocks of wood in the concrete so as to impair its strength materially, show negligence in construction.

THE CORONER'S VERDICT.

The verdict of the Coroner is in substance as follows :—

At the time of the accident the shell of the building was completed except that the face walls, which were of brick, were being built; the waterproofing of the roof was being put on, but had not reached the corner which fell, and workmen were removing the wooden supports under the portion that collapsed.

I find that the building collapsed because of the crushing of the lower portion of the steel-concrete column which is the sixth from the south side in the third row from the east side and marked No. 47 on the detailed construction plans. And Col. 47 crushed because it was improperly designed for the material of which it was composed and for the duty assigned to it, and the concrete was

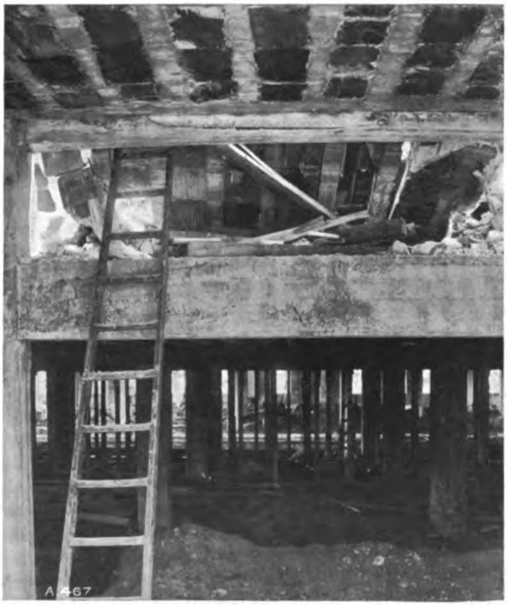


FIG. 5.

---

*The roof is 6 in. thick in one bay, 10 in. thick in the next. The mezzanine floor is absent on one side of the column.

not properly compacted by tamping and its concrete was weakened by the presence of chips, leaves, sawdust and blocks of wood.

I find the Concrete, Steel & Tile Construction Co., of Detroit, guilty of criminal negligence in submitting the working drawings, not in conformity with the agreement with the Eastman Kodak Co., and allowing pressures upon these columns beyond any safe limit.

I find William Costello guilty of criminal negligence, because, while in charge of the construction for the Concrete, Steel & Tile Construction Co., he allowed the cement to be put in the forms without proper tamping, so that holes were left in it, and allowed four steel rods to be put in a column where the plans called for six rods, and allowed four rods to be put in Col. 47 when the plans called for eight rods; and by gross and culpable negligence permitted leaves, sawdust, chips and blocks of wood to be put in the columns, thereby endangering the safety of the building.

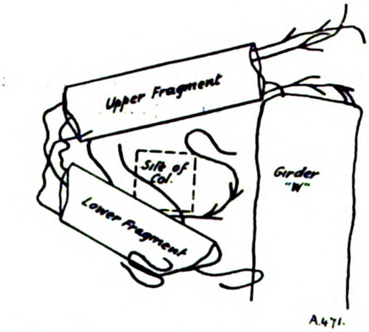


FIG. 6. SKETCH PLAN OF LOCATION OF COLUMN 47 IN THE RUINS. (GIRDER D. NOT SKETCHED)

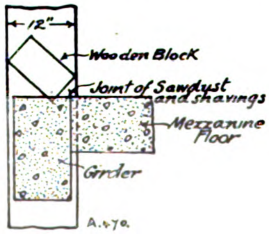


FIG. 7. WOODEN BLOCK IN COLUMN 47.

I find Perley S. Wilcox, assistant manager of the Kodak Park works of the Eastman Kodak Co., who is an educated engineer and experienced in the construction of buildings, to be guilty of gross and culpable negligence; for the reason that, while the evidence shows he had and exercised control over the work of this construction on behalf of the Eastman Kodak Co., and had power to change the working plans and have removed defective construction and have careless workmen discharged, and even to stop the work, he, by gross and culpable negligence, allowed the contract to be violated so as to endanger life, by permitting Col. 47 to be constructed far weaker than was called for by the original plans made under his direction, and weaker than allowed by the building ordinances of the city of Rochester, although the contract specified that the plans should conform to such ordinances; and he was guilty of gross and culpable negligence when, recognising his responsibility of inspection of the work in progress, he allowed to be employed a teamster, utterly devoid of experience in building, as sole inspector, without instructions as to the importance of the work he was inspecting, so that the moral effect of such inspection was bad, except, possibly, for impelling haste in the work rather than care for its integrity. He was guilty of gross and culpable negligence in not removing work which was obviously defective, like blocks of wood and joints of sawdust at the bases of the columns, when the contract specified as follows:—

> The contractor agrees that the owner shall have power to cause any improper, inferior or unsafe work to be taken down and altered, and that all improper, inferior and unsafe work will be taken down and altered at the cost of the contractor and without charge or expense to the owner * * * and if at any time the contractor shall refuse to remove any work or materials rejected by the owner, then, and in that case, the owner, or such other agent as the owner may designate, may, upon five days' notice, declare this contract forfeited * * * the same as if this contract had never been made.

He was guilty of gross and culpable negligence in permitting Col. No. 47 to be constructed so that it would be subjected to a stress considerably greater than is consistent with or is considered safe in any building ordinances or engineering practice that has been brought to my knowledge.

CONCLUSIONS OF FACT.

I also draw the following conclusions of fact from the evidence and the study of this accident:—

First—The "Kahn" bars, and similar bars, with shear members attached, are not suitable for columns, because of difficulty in properly tamping the concrete.

Second—No steel-concrete structure can be considered safe unless some reliable man is absolutely responsible for putting the proper number of proper sized bars in the positions designated for them.

Third—The allowable stress upon steel and concrete in construction should be fixed by law, so that the safety of the public will not depend upon the cupidity of energetic contractors or parsimonious designers.

I recommend to the Monroe county delegation in the Legislature that:—

Chapter 415 of the laws of 1897, known as the "Labour Law," which provides for the protection of labour in the building and operation of factories in cities, should be enlarged so as to provide for the approval of plans and supervision of construction of factories which are located outside of cities, as it is well known that one of the strong reasons for building factories in the country is to escape the interference of public officials and avoid the additional expense of construction which a compliance with public building ordinances implies.

December 20, 1906.

THOMAS A. KILLIP, Coroner.

LOCAL REQUIREMENTS.

The contract for the construction of the building made no specifications as to stress, but provided that—

"the said work is to be completed in strict conformity to all building laws, ordinances and regulations of the City of Rochester and State of New York."

The Rochester building ordinances contain the following clause, which is of special importance in view of the above agreement:—

"The safe bearing load to apply to concrete when Portland cement is used shall be taken at 15 tons per superficial foot.

The load is equivalent to about 208 lb. per sq. in. The ordinances also define "reinforced concrete" and "armoured concrete," and prohibit concrete columns above the first floor.

THE VIEWS OF THE BUILDING OWNER.

The building owners, the Eastman Kodak Co., of Rochester, N.Y., have sent us the report of Messrs. Edwin Thatcher and C. W. Marx on this failure, the former a well-known specialist in reinforced concrete, the latter, until recently, a Professor at the University of Cincinnati, in which city reinforced concrete has been used to a considerable extent.

The owners of the building state that the opinion expressed in the report appears to be borne out by the views of the majority of independent engineers who have visited the scene of the failure. The owners lay stress upon the fact that portions of the collapsed

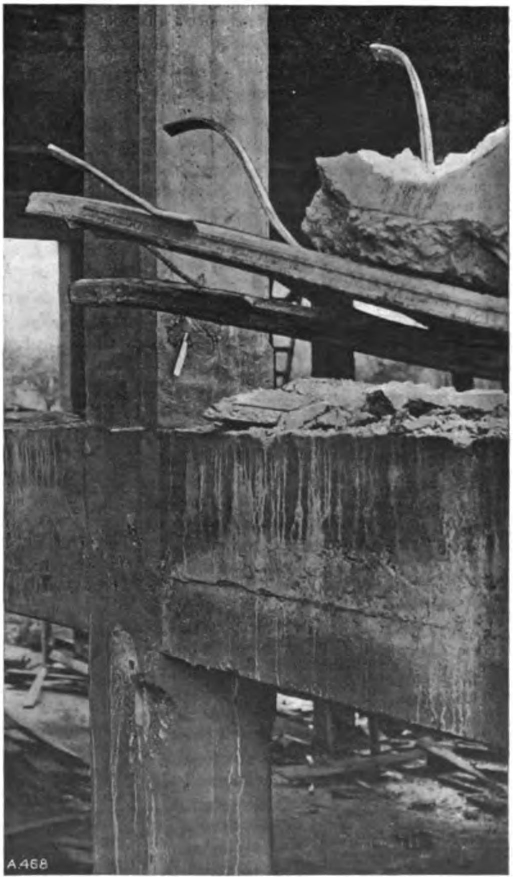


FIG. 8.

building were soft, i.e., not set at the time of the collapse, but that though soft the material was good and the proportions of material used usual ones.

Finally, they intimate that the contract was on a "cost plus a fixed sum" basis, not dissimilar to what would be called here a "prime cost plus profit" basis, and that there was apparently no monetary reason why the contractor should have used bad material or scamped the work.

The report is given below in full:—

Expert Report of the Building Owners.

Rochester, N.Y.
December 31st, 1906.

To the Eastman Kodak Company, Rochester, N.Y.

Gentlemen,—As per your request we have examined the concrete-steel tile construction in your emulsion building, especially that portion tributary to column 47, and beg leave to make the following report as to the cause of the collapse.

We are fully convinced that the primary cause of the failure was due to the fact that the supports under girders and floor construction were removed too soon for that season of the year, your records showing that the concrete was only about three weeks old. The concrete throughout is of good quality but was too green (*i.e.*, not sufficiently hard) to enable the respective members to even carry their respective dead loads with safety. Had the forms around the columns and sides of the large beams been first removed and the supports under girders and floor construction left undisturbed for a period of at least four weeks longer, it is our opinion that you would not have experienced the slightest trouble.

We do not find that any abnormal or eccentric loading exists.

The girders tributary to column 47 were constructed and executed with ample factor of safety. We find that the dead load of roof construction coming on column, equals	45,000 lbs.	
The dead load from mezzanine floor construction	16,300 „	
Making the total dead load of roof and mezzanine floor construction (together with the weight of column) on column 47 equal		61,300 lbs.
Live load from roof	29,700 lbs.	
Live load from mezzanine floor	16,000 „	
Total live load on column 47		45,700 „
Combined dead and live load on column 47		107,000 „

Cross sectional area of column 47, equals	144	sq. in.
Steel area	2·24	„ „
	141 76	„ „
15 times steel area	33·6	„ „
Total effective area reduced to concrete, equals	175·36	„ „

The unit dead load stress on column 47 equals 61 300 divided by 175, equals 350 lbs. per sq. in.

The unit dead and live load stress on column 47 equals 107,000 divided by 175, equals 612 lbs. per sq. in.

It is customary to reduce the live load as it comes on to the girder and column for the reason that owing to the necessity of passage-ways only 80 per cent. of the floor can be loaded; therefore using 80 per cent. of the live load on mezzanine floor, the total unit stress per sq. in. of column 47 equals 103,000 divided by 175, equals 594 lbs. per sq. in.

In our calculations we used an ultimate compressive stress on concrete (mixed as in your building) of 3,000 lbs. per sq. in. Using a factor safety of 4 will give 750 lbs. per sq. in. as a safe working stress. On steel as used in your building we allowed an ultimate tensile stress of 64,000 lbs. per sq. in., which, with a factor safety of 4, will admit of a safe working stress of 16,000 lbs. per sq. in.

We further submit the following detailed report of actual test conducted on column 43, together with photographs herewith. Column 43 is constructed the same as was column 47.

The marked prints herewith show areas of roof and mezzanine floor that were loaded with tile—

The red tile were 12 in. by 12 in. by 4 in. and weighed 21 lbs. apiece.
" Yellow " were 12 in. by 12 in. by 4 in. and weighed 17·75 lbs. apiece.

Owing to the fact that the area tributary to column 43 is smaller than the area tributary to column 47, increased unit live loads were used in order to produce an excess column load.

The area marked is 40 by 31 equals 1,240 sq. ft.; the total weight of tile on this area uniformly distributed equals 80,000 lb. The weight per sq. ft. of loaded area equals 80,000 divided by 1,240 equals 64·5 lbs. The additional central load placed directly over column occupied a space 10 ft. by 10 ft. and weighed 21,200.

The total dead load of roof supported by column 43 equals	41,250
The total live load of roof supported by column 43 equals	42,980
The total dead and live load of roof including column supported by column 43 equals	84,230

The mezzanine floor was loaded with five courses of red tile and one course of yellow tile, total weight per sq. ft. equals 122·75, allowing 5 per cent. for unloaded areas will give a uniform load of 122·75, divided by 105 equals 117 lb. per sq. ft.

Area of mezzanine floor supported by column 43 is	163 sq. ft.
Mezzanine floor live load equals 163 × 117, equals	19,100 lbs.
Mezzanine floor dead load equals 163 × 83, equals	13,500 „
Girders A and C	1,905 „
Column 43, mezzanine floor to floor below, 8·5 × 144 equals	1,220 „
Total dead and live load from mezzanine floor transmitted to column 43 equals ...	35,725 „
Total dead and live load from roof transmitted to column 43 equals	84,230 „
The combined dead and live loads from roof and mezzanine floor transmitted to column 43 equals	119,955 „
The estimated combined dead and live loads from mezzanine floor and roof transmitted to column 47 equals	107,000 „

$\frac{119955}{107000}$ equals 112 per cent., or test load was 12 per cent. greater than load for which column was designed. This gives a unit stress per sq. in. of $\frac{119955}{175}$ equals 687 lbs.

As before stated, it was found necessary to increase the unit live loads; this gave a unit load on roof of 64·5 lbs. or $\frac{14.5}{50}$ equals 29 per cent. more than specified. The live load on mezzanine floor was 117 lb. per sq. ft. or 17 per cent. more than specified.

The deflection under mezzanine floor with 117 lb. per sq. ft. was $\frac{3}{16}$ of an inch.

The deflection of roof was $\frac{3}{32}$ in. in middle of 21 ft., and 19 ft. spans. These deflections are very small considering the loads.

Yours truly,
(Signed) EDWIN THATCHER.
(Signed) C. W. MARX.

Some Early Examples of Reinforced Brickwork Tanks in our Imperial Possessions.

By JAMES STEWART, M.Inst.C.E.,
Auckland, N.Z.

It is always pleasant to be able to present contributions by readers of this Journal in distant parts of the Empire, and we, on this occasion, publish some data which will be interesting reading to all at home. We hear so much about reinforced concrete that the value of reinforced brickwork should not be overlooked. There are also numerous combinations of reinforced concrete with brickwork, and reinforced brickwork with concrete covering that certainly merit the attention of members of the technical professions.—ED.

It is probable that the first instance of reinforcement of brickwork by imbedded iron cannot now be more than approximately determined. The celebrated engineer, Sir M. I. Brunell, made some experiments more than 60 years ago, which demonstrated in a striking manner the advantages to be gained by a judicious use of what has ever since been termed "hoop iron bond," and it is quite probable that the idea originated with that gentleman, from whom originality of design and boldness of execution seemed to be inseparable.

Since Brunell's time, hoop iron has been used quite extensively to strengthen brickwork, masonry, and concrete. But its proper and safe application, by being thoroughly embedded in mortar, is troublesome and quite exceptional, and the improper method of laying the iron on a dry bed, as too often practised, is a source of weakness instead of strength, caused by the rapid rusting of the iron and consequent enormous increase in bulk. To such an extent does this obtain, that within the writer's knowledge the walls of one of the principal hotels in Auckland were lifted in each course, where hoop iron had been improperly laid, from the oxidation resulting from the underside of the iron not having been embedded in mortar. The hotel in question was, in consequence, and at great loss, pulled down to the foundations and rebuilt.

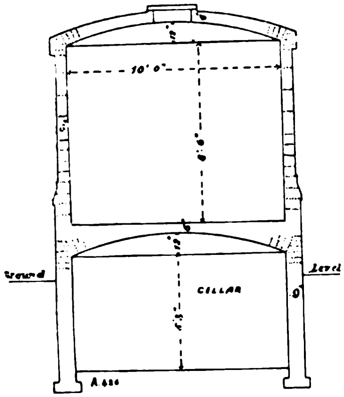


FIG. 1.
TANK AT MATAMATA STATION, ON ROTORUA RAILWAY, NEW ZEALAND

Early in 1867 the writer had occasion to build a circular brick cistern, partly sunk in the ground and covered with a flat segmental dome, the springing of which, being from 9 in. walls, above ground level, and

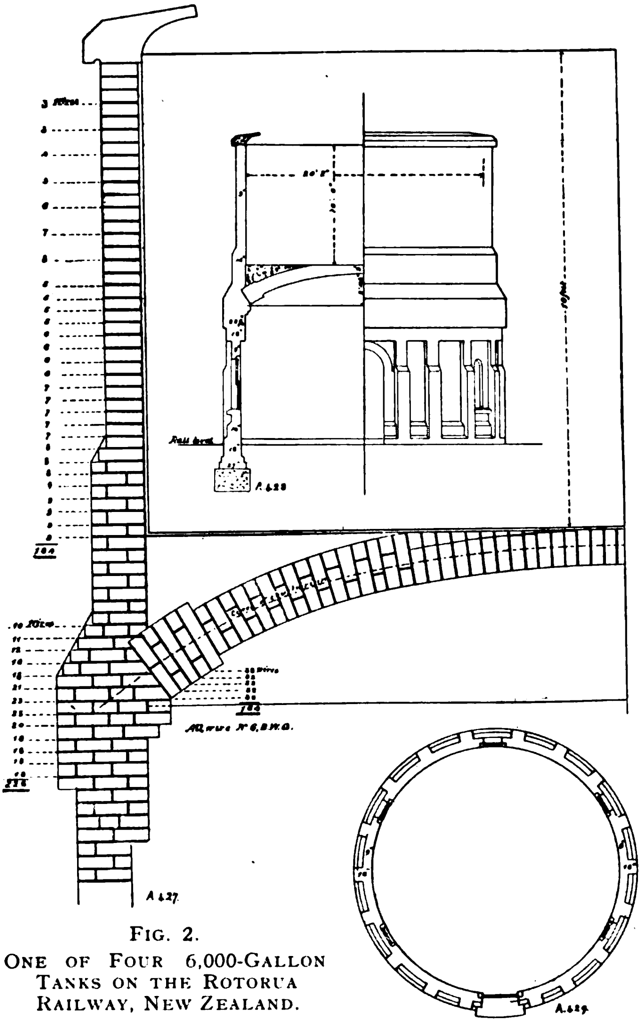


FIG. 2.
ONE OF FOUR 6,000-GALLON TANKS ON THE ROTORUA RAILWAY, NEW ZEALAND.

thus deriving no extraneous support, reinforcement of some sort became necessary. Although hoop iron with care and proper method is used with excellent effect in straight walls, it is altogether unsuitable for circular work, and in consequence the writer thought of, and used, wire. It was laid in the skewback in a continuous conical spiral, and the facility of application, the ease and thoroughness with which it was enveloped in mortar, although laid on the dry bed, and its special adaptability to all circular work, appealed so forcibly to the writer's sense of the fitness of things that he has used it subsequently on all work of that kind which came under his direction.

This use of wire being, so far as the writer was concerned, original, he naturally neglected no opportunity of ascertaining if it had been used for the purpose in any such work prior to the date mentioned. He has, however, failed to find any instance of such. The date of Monier's use of wire-netting in reinforcing his large shrub tubs is stated by Sabin as 1876. Marsh puts it as 1867, which, from the obituary notice in the July number of *Concrete and Constructional Engineering,* is evidently the correct date, although it was only in the later "seventies" that Monier arches and other structures came into notice.

In Marsh's standard work* are given 43 systems of reinforced concrete. Of these only three—viz., those of Coignet, Monier, and Pavin de Lafarge—deal with circular reservoirs or cisterns, the reinforcement being principally by rods and hoops. In the appendix, Marsh gives a full and illustrated description of the structure of brick cisterns built in India by Major Stokes-Roberts. This is the only instance in which the writer has found any approach to the use of wire, but the method of its application is (literally) diametrically opposed to that employed by him. The Major uses wire laid radially in the wall, and in the segmental dome, the thrust of which is taken up by old tram rails, formed into a circle, and embedded in the skewback. The thrust due to the head of water is, on the cylindrical wall, taken up by external

---

* This article was written prior to the third edition reaching New Zealand.

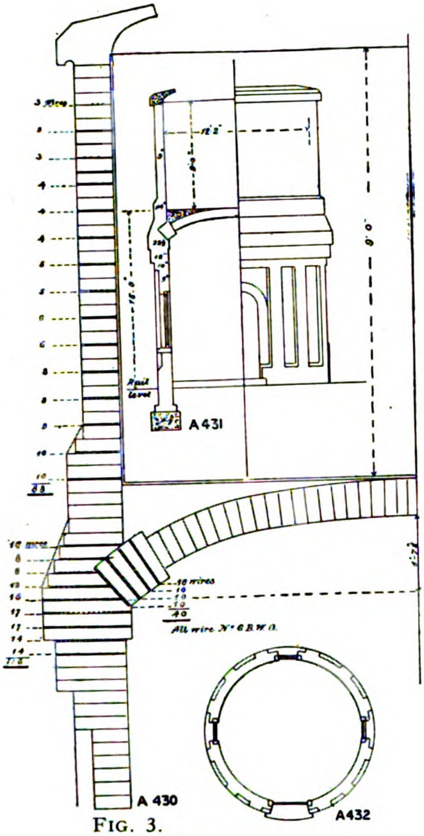
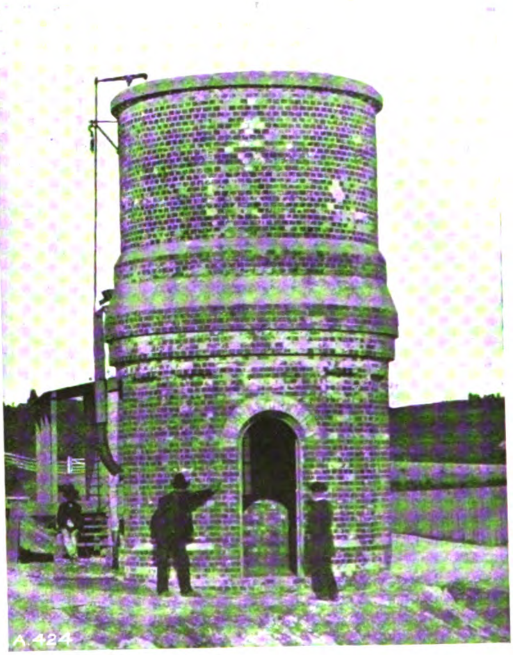


FIG. 3.
TANKS IN AUSTRALIA.

bands, or chains formed of short pieces of wire or rod linked together, and forming, in the writer's opinion, a not very solid or secure reinforcement. The accompanying drawings of several of the structures erected in the writer's practice show how radically different is his system from that as above described.

Subsequently to 1867 ten cisterns with wire reinforcement have been erected from the writer's designs. These vary from 20,000 gallons to 4,000 gallons capacity. Of these only the three following designs need be described, viz. :—One 4,000 gallons elevated concrete tank, with cellar underneath, built in 1873 personally by the writer at his residence to illustrate the system and method (*Fig.* 1). In 1885 one elevated brick cistern, 20,000 gallons capacity, for locomotive supply, with store underneath, erected at Matamata Station on the Rotorua Railway (*Fig.* 2), and four tanks on the same line, each 6,000 gallons, at Tirau, Putaruru, Lichfield, and Ngatira Stations (*Fig.* 3). The foreman builder of these railway tanks, being in possession of the working drawings, proceeded to Australia, and erected there a number of similar tanks, the position and particulars of which are unknown to the writer.

The writer at first used hard, bright wire, but in all the instances as above the wire was ordinary black annealed fencing, No. 6 B.W.G. It is laid in the brick or concrete beds continuously in true spirals, plane on the flat beds, and conical on the skewbacks. The location and amount of the wire is, of course, in accordance with the direction and value of the calculated strains, the maximum stress on each

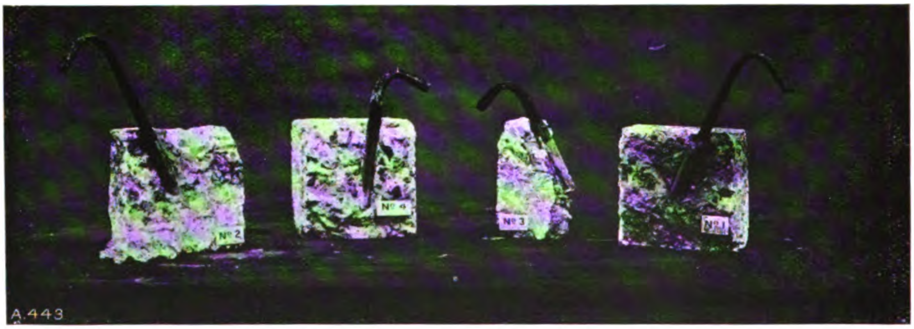


TANK ON ROTORUA RAILWAY, NEW ZEALAND.
(1887).

wire being fixed at 200 lbs. Taking the strength of ordinary black wire at 28 tons per sq. in., this means a factor of safety of 10, which, under the circumstances, was adopted. But with our present knowledge of the ratio of the moduli of steel and concrete, and the use of steel wire of 70 tons strength, a factor of safety of 6 may be adopted, and each No. 6 wire be loaded to 800 lbs. Hard, bright wire is much easier laid in the spirals. Black wire must be cleansed from all paint or other coating. Considerable care is necessary in laying the wire to ensure regularity of pitch and accuracy of spirals. This is easily effected by the use of notched sticks, numbered and laid radially in order, about 2 or 3 ft. apart, the notches being cut so as to lead the wire into a regular spiral.

The result has been in each case very satisfactory, but the economical proclivity of the Public Works and Railways Departments of New Zealand leads to a preference for wooden tanks, and it was only from the circumstance that the writer had a leading voice in the construction of the Rotorua Railway that the five wire reinforcement tanks on that line were built.

The system of wire reinforcement as above described, while applicable to all circular structures in which no bending or overturning moments have to be provided for, is not so well adapted for tall factory chimneys and such like, when vertical reinforcement is necessary. In such cases, the vertical rods now used are essential, and as their position would interfere with the laying of wire spirals, the diametrical stresses, which in chimney stacks are not severe, may best be taken up by circular rods or bars as at present practised.



FIGS. 1 AND 2.
(EXPERIMENTS AND TESTS WITH REINFORCED CONCRETE.)

A FEW EXPERIMENTS AND TESTS WITH REINFORCED CONCRETE.

By R. T. SURTEES, Water Engineer, Newton-le-Willows

It is with particular pleasure that we present this article by Mr. R. T. Surtees, for it is but rarely that we can obtain the records of research work produced by workers in actual practice, and we consider that enquiry by men who have actual experience in the execution of work similar to that in which they are making their investigations is of the highest possible importance.

We naturally esteem all scientific research work from that great band of scientists and others solely engaged in investigation, but we have found in such cases where a mind influenced by practical experience is brought to bear, that the results obtained are more truly useful to the members of the technical professions in private practice.—ED.

The use of reinforced concrete has, during the last few years, made considerable headway in Great Britain, but it is surprising to find how far we are behind our neighbours on the Continent of Europe, and also America, in this form of construction. As a nation we look with suspicion upon new ideas and new things, and perhaps in no professions is this more so than in the Architectural or Engineering. We like to see a thing well tried before we adopt it, and in several ways reinforced concrete is so different to what we have been used to in the ordinary systems of building construction, and has such far-reaching effects, that slow progress in its more general use may, to a certain extent, be excusable. It may now, however, be safely said that the initial stages of its introduction have been left behind, and if we scan the pages of most of our professional journals we find much more space devoted to it than was seen even so recently as four or five years ago, and to go back a little further, it is seldom mentioned at all. We can now see buildings of considerable magnitude and intricacy that have been successfully erected which, for strength, lightness and cheapness, have come out most surprisingly in comparison with either brick, stone or constructional steel erections, and it has been well said that it is more difficult to find an instance in either architectural or engineering practice in which reinforced concrete cannot with advantage be used than to cover the whole field of its operations. In some classes of work, even with the limited competition, the saving in first cost has been incredible, whilst in annual maintenance the points are greatly in its favour, when compared with the above-mentioned systems of construction, and undoubtedly the more it becomes known the more will it be used. At present the designing and erecting of buildings of this material is principally in the hands of those who have patented some detail in connection with its construction; but the time is not far distant when experts, standing high in the aforesaid professions, will be found, and perhaps this more than anything else will give its more general adoption a great impetus, for it is repugnant to many to have to place their work in the hands of a patentee to carry out on his system, without being able to have it checked by an unbiassed and independent authority. Architects and engineers are also beginning to realise the necessity for qualifying for this class of work, for the more advanced see that it has come to stay, and those who are unable to undertake—or at least advise on—reinforced concrete will be left behind in the race.

People, when having the details of this material described to them for the first time, invariably ask if the concrete will preserve the steel from rust, and even experts are not yet satisfied as to what aggregates will, and what will not, have an injurious effect. It has been found that iron cramps, after being surrounded with concrete for hundreds of years, have been proved to be in perfect condition, whilst it has been equally proved that steel embedded in concrete floors for only a few years has been affected to such an extent that the wonder was that a collapse had not taken place. What is the cause of this great difference? Is it the chemical composition of the steel or the aggregate, or is it due to the mixing or placing of the concrete? The following experiments have been carried out with a view of ascertaining a correct answer to these questions, so far as the concrete is concerned, and to many, I am afraid, the results will be, in one or two instances, rather unexpected.

With aggregates of various materials concrete blocks were made up, in which were inserted pieces of steel, with their ends projecting out of the mass for a few inches. These blocks were immersed in water at frequent intervals for a period extending over twelve months, when the projecting ends of the steel were found to be highly corroded. They were then submitted to the action of steam from a boiling solution of acid until the exposed steel was, in most instances, practically destroyed. The blocks were then cut open so that the embedded portions of the steel could be inspected. *Fig.* 1 is from a photo. of some of these blocks, the concrete in which was made with an aggregate composed of blast furnace slag from the works of the Wigan Coal and Iron Co. *Figs.* 2 and 3 show other blocks included in the table, which also gives the results of the experiments.

FIG. 1.

No.	Aggregate.	Sulphur.	Concrete over Steel.	Remarks.
1.	Blast furnace slag	2·07 per cent.	1¾″	Steel not affected.
2.	,, ,, ,,	2·07 ,,	½″	,, ,, ,,
3.	,, ,, ,,		⅜″	,, ,, ,,
4.	,, ,, ,,		1¾″	,, ,, ,,
5.	,, ,, ,,		1¾″	,, ,, ,,
6.	,, ,, ,,		½″	,, ,, ,,
7.	,, ,, ,,	2·07 ,,	¾″	,, ,, ,,
8.	,, ,, ,,	2·07 ,,	1½″	,, ,, ,,
9.	Boiler furnace clinker		2″	,, ,, ,,
10.	Crushed bricks		2″	Corroded from honeycomb in concrete.
21.	Boiler furnace clinker		1¾″	,, ,, ,,
23.	Crushed bricks		2″	,, ,, ,,
25.	Brick and clinker		2″	,, ,, ,,
27.	Crushed bricks		1¾″	,, ,, ,,

In Nos. 2, 3, 6 and 7 the bars were nearer the outsides of the blocks than is usual in reinforced work, and yet nothing penetrated the concrete far enough to cause rust to form on the steel.

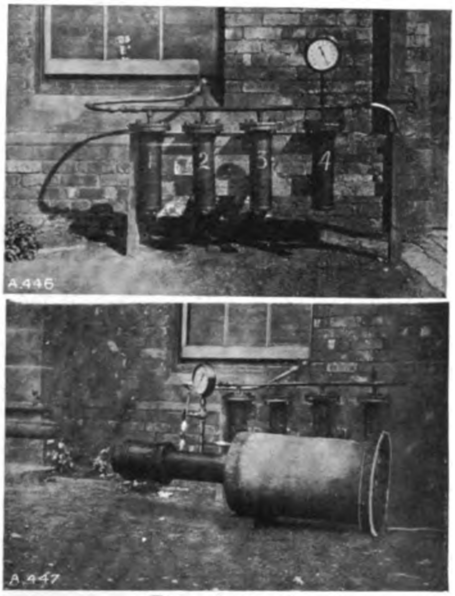
The amount of sulphur in Nos. 1, 2, 6 and 8 was sufficient to colour the concrete to a dark green, and there appeared to be no deleterious action set up on the steel.

There was a large amount of iron in the clinker which did not show any effect on the embedded steel when the concrete was properly consolidated and without voids.

In all cases where the steel showed corrosion the concrete had not been properly graded, or made free from honeycombs or voids, which in most cases were easily traceable right from the steel to the outside of the blocks.

The whole of the concrete used was made with aggregates containing the run of the crusher, none of the fine dust being kept out.

These experiments indicate that to effectually preserve the steel the aggregate for the concrete should be carefully graded to ensure the filling of the voids, that the concrete should be carefully mixed, placed and consolidated, and even if this mixture does contain certain chemical impurities, there is small likelihood of rust being formed. Great care should be exercised to prevent the possibility of air spaces, honeycombs or cracks on the outer surface extending into the mass far enough to allow an air passage to reach the steel, for if unnoticed or allowed to remain, rust will form which may burst off part of the concrete, and so weaken the structure that disaster will eventually result. A case which recently came under the writer's notice was caused by the timbers being removed by the workmen before the concrete had been properly set, when its own weight had caused it to fall away from the steel, just enough to cause a crack extending a considerable distance along the rods. No attempt had been made to remedy this, and after the contractor had handed over the work the evil results began to appear. In a case of this kind, the rusting of the steel may perhaps not be the least danger incurred, for the concrete might be materially damaged, whilst its adhesion to the steel would be far from what it ought to have been. Cinders, pan breeze and such like are undoubtedly attended with a certain amount of danger in their use as aggregates in concrete having direct contact with steel, when soft they will not stand ramming without crushing, and the crushed parts may not be coated with cement, consequently dampness may make through to the detriment of the steel. Cinder concretes have, no doubt, been the cause of failures, and in the hands of careless contractors are most dangerous to allow. A concrete made with them may, however, with advantage, be used under certain floors or in partitions where it is required to take nails for fixing boards or other timbers. It is also a poor conductor of sound and useful as deafening.



FIGS. 4 AND 5.

Under no conditions is a rich concrete, having an aggregate of hard, sound material, proportioned and placed so as to secure the greatest density, more necessary than for an impermeable concrete. A concrete of this kind is often required for cellars, reservoirs, tanks, pipes and such like. *Fig.* 4 shows a method of carrying out experiments with a view to securing the best results, and the apparatus being of simple construction will allow the test to be carried out on most jobs at little expense. In each of the four large pipes shown are blocks of concrete, 5 ins. in thickness, moulded inside. The larger pipes are connected to the town's water supply by means of the small pipe along the top, which allowed a pressure of 40 lbs. per sq in., means being provided to allow the enclosed air to escape. The arrangement shown is also connected to a small boiler feed pump by which the pressure could be increased to 260 lbs. per sq. in., the town's pressure being shut off by a small valve when this was being applied. The following table gives the composition of the concrete in each pipe :—

Number.	Uncrushed Gravel.	Crushed Gravel,	Added Sand.	Cement.	Size of Screen through which Gravel passed.
1	2½ pts.	2½ pts.	3 pts.	2 pts.	½″
2	3 ,,	3 ,,	2 ,,	2 ,,	½″
3	4 ,,	2 ,,	2 ,,	2 ,,	¾″
4	3 ,,	3 ,,	2 ,,	2 ,,	¾″

The aggregates included the fine stuff contained in the whole run of the crusher. The pipes were allowed to stand under damp cloths for two days, and afterwards were immersed in water for eighteen days, the test being applied on the twenty-first day after the concrete was placed. The results of the tests are as follows :—

Date after applying pressure.	Pressure applied in lbs. per sq. in.	No. 1. *	No. 2. *	No. 3. *	No. 4. *
1	35—50	36·60	5·37	none	none
2	,, ,,	20·00	1·91	,,	,,
3	,, ,,	12·00	·986	,,	,,
4	60—70	30·00	3·25	,,	,,
5	35—50	14·66	·62	,,	,,
6	,, ,,	7·50	·332	,,	,,
7	,, ,,	6·00	·32	,,	,,
8	,, ,,	7·57	·427	,,	,,
9	,, ,,	6·00	·083	,,	,,
10	,, ,,	5·83	·041	,,	,,
11	,, ,,	5·25	none	,,	,,
12	,, ,,	6·00	,,	,,	,,
13	,, ,,	6·33	,,	,,	,,
14	,, ,,	5·83	,,	,,	,,

* In centilitres per hour.

Continuing at near this rate until the thirtieth day, when the experiment was considered sufficient.

Having proved a satisfactory mixture, from the materials to hand, an attempt was next made to find out the best conditions under which the concrete would set, for should contraction take place, cracks might occur, through which water could pass. With this object in view four more pipes were used, in each of which was placed a thickness of 5 ins. of concrete, prepared in a similar manner to those giving the best results in the preceding experiment. No. 1 was placed in a position to set where a hot sun could get at it during most part of the day, No. 2 was placed in a shaded place, and Nos. 3 and 4 were allowed two days under a damp cloth, twenty-eight days immersed in water, and all were put under pressure on the thirtieth day. The concrete in No. 1 had contracted in setting as water passed between the pipe and the block of concrete inside. No. 2 showed a very slight dampness, which soon took up, whilst Nos. 3 and 4 were perfectly watertight. The set of pipes shown in *Fig.* 4 were made up of Nos. 3 and 4 of the former experiment, renumbered respectively 1 and 2, with Nos. 3 and 4 of the latter. The pressure was again applied, being gradually increased up to 260 lbs. per sq. in., and after two days with it varying between 50 lbs. per sq. in. and this, during which no signs of dampness appeared on the underside, one of the blocks was cut out to see how far the water had penetrated into the mass of concrete, where it was seen to be traceable for a distance of only 1⅛ in. Whilst it may not be a difficult matter to make blocks of this size to stand such high pressures it could hardly be expected that a long thin wall of the same materials would give the same results, there being so many other factors to contend against. Following this investigation as a step further a reinforced concrete pipe was made, as seen in *Fig.* 5.

This was first made with an open end, and after the concrete had set a short length of cast-iron pipe—for a special purpose other than connecting the hydraulic pressures—was moulded on to the end, the longitudinal steel reinforcing rods passing through the pipe, and well into the concrete securing the cap. After connecting up the pipes, pressure at the rate of 30 lbs. per sq. in. was applied, being gradually increased until it reached 120 lbs., with no signs of dampness appearing on the outside of the pipe. This pressure was maintained for three hours, and on attempting to raise it higher the joint between the first-made concrete and that fixing the cap gave way, and as the object of the experiment had been attained no further attempt was made to reconnect it.

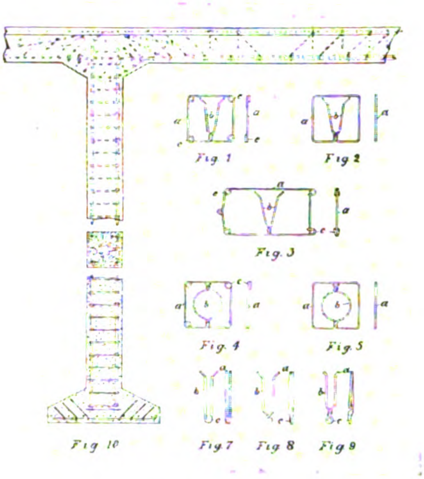


FIG. 6.

Reinforced concrete pipes without the assistance of internal metal tubes to stand a pressure of this severity require great care in their construction, and a little remissness in mixing, placing or consolidating the concrete may lead to failure. In all the above percolation tests the aggregate used was from Walney Island, and the Portland cement was to standard specification.

To secure the best results under direct compressional loads, as in columns and such like structures, it is imperative that the main or vertical reinforcing bars should be so fixed as to secure the requisite size of core, to be hooped or bound with a wire wrapped spirally around the steel skeleton, to the bars of which it may be tied with fine wire; or with wire hoops; or with links, each having encircling fitments to take the bars; or with links from bar to bar, having loose struts put between the verticals to keep them tight against the ends of the links. Hooping may consist of horizontal hoops, welded, bolted or riveted at the ends to form a continuous band, to the shape of the column, or wires may be used having their ends twisted to form a secure fastening. These are placed around the vertical bars at proper intervals in accordance with the strength demanded. Encircling fitments added to a few of these forms of hoops, to hold the bars in their exact position, are well worth the little extra expense, as they serve both to connect the bars together and hold them apart from

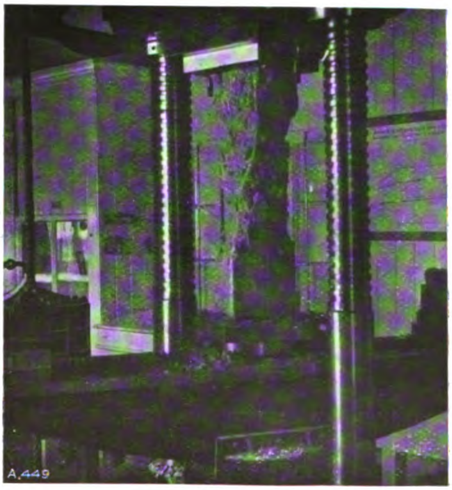


FIG. 7.

each other, so that the core cannot be otherwise than the size and shape designed. The spirally-wound skeleton has been often thought one of the strongest systems, but is difficult to apply, and as the whole skeleton has to be built up in position before any of the concrete is placed it makes this difficult to do, and what may be gained in stronger skeleton may be lost by a weaker concrete; and should the continuous wire wrapping get damaged at any one place in its length it materially weakens the whole length of column, whilst one break in it practically destroys the whole length of hooping. With any form of skeleton, however well it may be made, care is required in ramming the concrete, and care should be taken to ensure as little

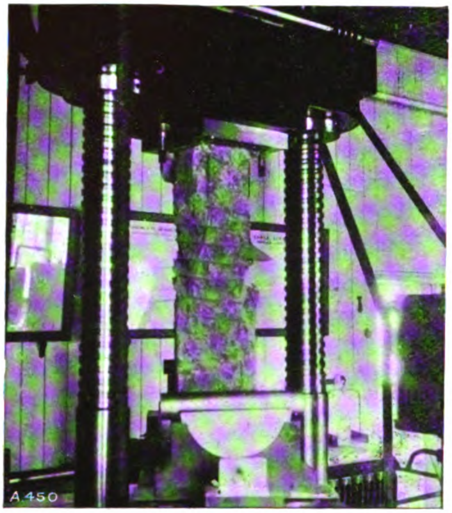


FIG. 8.

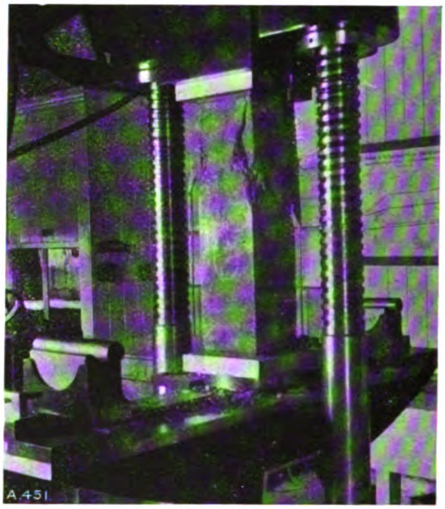


FIG. 9.

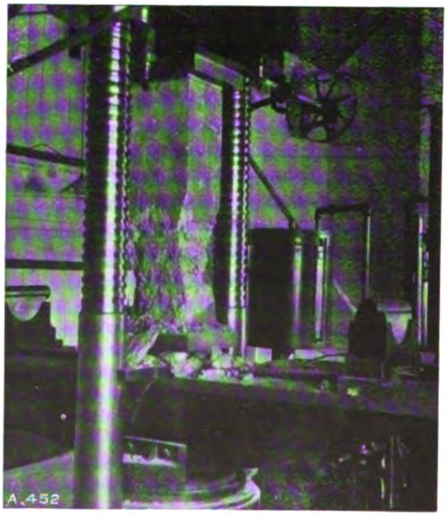


FIG. 10.

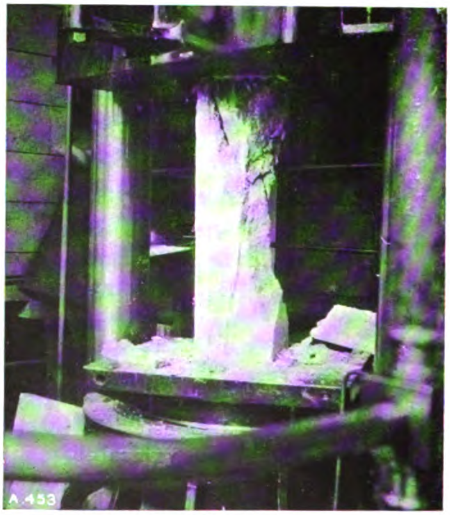
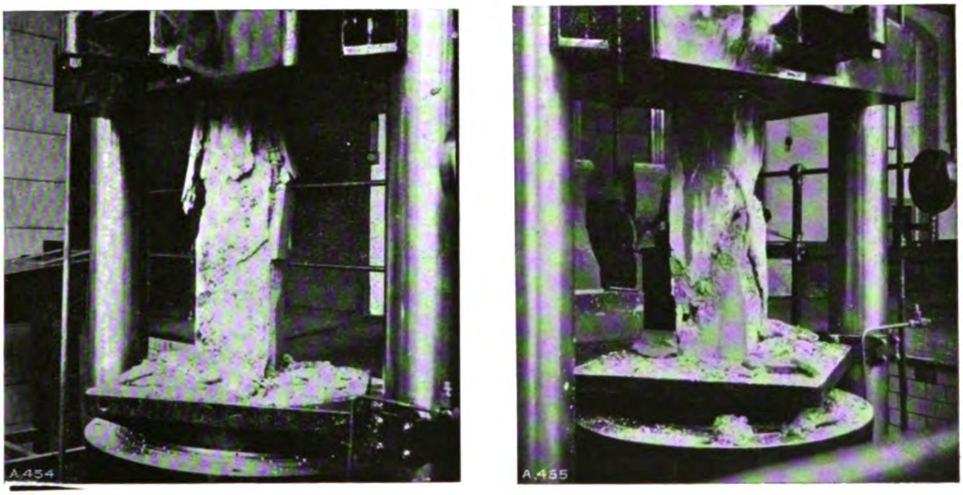


FIG. 11.

obstruction as possible to this, and even if the steel is made up into units they may be thrust out of place by careless workmen who do not realise the importance of what they are doing.

It has been contended that the advantage of a spirally-wrapped wire hooping lay in the fact that the spaces between the spirals was not in the same horizontal plane right around the column, as is the case with plain or with link hooping. This is doubtful, nor does the following experiment bear this out, although in this particular instance the hooping had the advantage of the ends of the hoops being so made that after the twisted tie they formed arms to lie through the core of the structure. These arms of the hoop were arranged in the mass of concrete in different directions to those of the next adjoining hoop, thus further reinforcing the core against that bulging action which is always set up when the load is applied. See *Fig.* 6. It is also probable that the horizontal hooping, as heretofore tested against wire wrapping, may have had the ends of the links simply laid side by side in the concrete, as was formerly the common practice, instead of having them securely twisted to form a tie, which ensures a structure being fully 23 per cent. stronger. The advantage of forming links for reinforced concrete work by uniting the ends in this manner, seems to have been first recognised by Newby, as described in his patents. It may be a simple matter to keep the steel members in their correct position in making a small test piece, but in actual work the difficulty is very great.



FIGS. 12 AND 13.

Instances have been known where the steel members have been found far different to where the designer intended

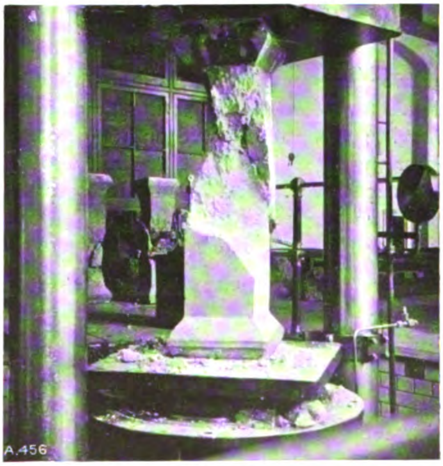


FIG. 14.

they should have been placed, and even in test pieces where every care had been taken to ensure correct work, members have been discovered out of place. Systems giving simplicity in design and execution, with secure fixing of the steel as the work progresses, have much to commend them.

It cannot be expected to make a structure of greater strength than its component parts, therefore we may look to get the best results under compressional loading, with a concrete having an aggregate of the hardest materials.

Figs. 7, 8, 9 and 10 show a set of columns made as nearly as possible under identical conditions as regards aggregates, sand, cement, mixing, placing and consolidating the concrete, special efforts being made to ensure that the whole should be as uniform as they could be made. *Figs.* 7 and 8 had the longitudinal bars spirally wrapped, and *Figs.* 9 and 10 had horizontal hoopings, as illustrated in *Fig.* 6, the steel in each instance being of the same weight throughout. *Fig.* 7 is of particular interest, inasmuch as it indicates a peculiar twisting action, which is perhaps attributable to this form of hooping when under load. As it happened, the pin which holds the table of the testing machine in position had been accidentally left out, thus leaving it free to move on its pivot, and after the application of the pressure the column began to twist to failure, the table moving around in unison therewith, destruction being achieved with a load of 49 tons. *Fig.* 8 was tested with the table fixed and failed under a load of 55 tons. *Fig.* 9 failed under 85½ tons, and *Fig.* 10 under 91½ tons. The specimens were all 2 ft. 6 ins. long by 8 ins.

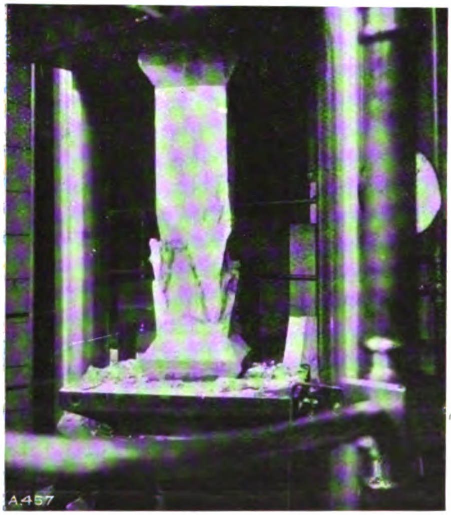


FIG. 15.

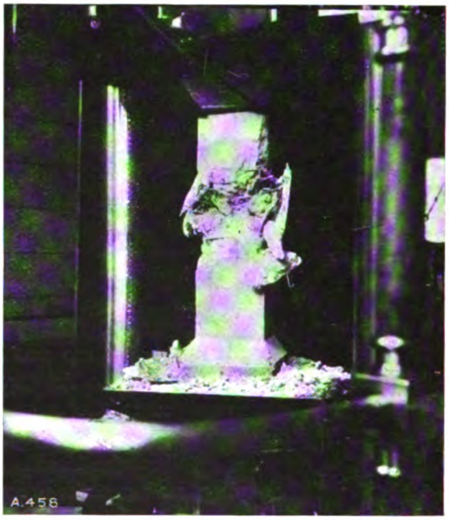


FIG. 16.

[*Note that Figs. 9 and 10 failed, through the ends splintering before their full strength was developed.*]

Figs. 11, 12 and 13, and 14, 15 and 16 illustrate respectively two sets of columns, the experiments being carried out as before, the concrete being prepared and the work executed with a view to securing uniformity throughout. The longitudinal bars were thirteen-sixteenths of an inch in diameter in all cases, there being a slight difference in the spacing of the hoops which were of the link and strut pattern.

No.	Crushed at		Size	by	by
No. 11	Crushed at 134½	tons.	Size 3 ft.	by 10 ins.	by 10 ins.
,, 12	,, ,, 176	,,	,, ,,	,,	,,
,, 13	,, ,, 209	,,	,, ,,	,,	,,
,, 14	,, ,, 219	,,	,, 4 ft.	,,	,,
,, 15	,, ,, 197	,,	,, ,,	,,	,,
,, 16	,, ,, 215	,,	,, ,,	,,	,,

It will be seen that *Fig.* 14, which is made with concrete having no reinforcing steel in it, comes out stronger than any of the others. In this case the failure took place suddenly and with a loud report, as of an explosion, whilst pieces of the concrete flew about the room with dangerous velocity. It is undoubtedly one of those freaks which sometimes develop even after the greatest care has been devoted to the work of construction. In this case the whole of the details connected with their construction were personally supervised by competent engineers representing three different authorities.

If it were possible in actual work to consistently obtain a concrete of this superior quality and strength, reinforcing would not be so necessary. After breaking the sample of concrete showed to be very dense, with practically no pinholes in it, and hundreds of attempts might be made to make another to give such good results, without success. It shows the advantage of having the soft concrete of the right consistency and that there be no obstruction to its efficient consolidation.

The mixture used in the manufacture of the last two sets of columns was just something less than a wet one, and with those having the steel skeleton in the moulds the concrete could not be so thoroughly rammed as where there was no such obstruction; a bigger rammer could also be used, and it is undoubtedly due to these causes that such a high result was obtained in this particular specimen. *Fig.* 16 shows excellent design and construction.

In the columns comprising the last six experiments the concrete was mixed in a machine of the revolving drum type, which, after repeated tests, the writer is convinced made a concrete which was 16 per cent. stronger than could be turned out by hand mixing.

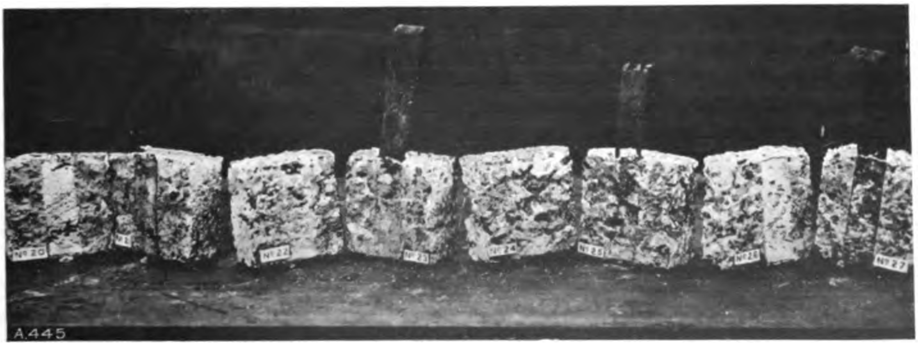
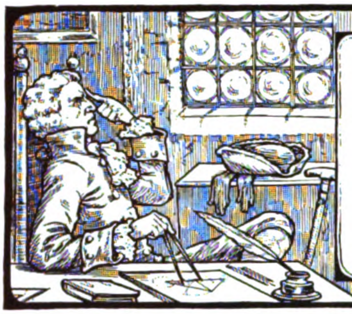


FIG. 3.



Theory and Application of Various Continental Methods of Calculations for Reinforced Concrete.

BY MONSIEUR N. DE TEDESCO.

Editor of "Le Ciment."

Designing in Reinforced Concrete being in so many ways a new subject to the British engineer and architect, we have thought it advisable to present an article as to the theory and application of various methods of calculations; and in calling upon Monsieur de Tedesco (the well-known editor of "Le Ciment") to prepare this article, we have been guided by the fact of his great knowledge of the practices in different Continental countries, and the authority his name carries, particularly in France. Perhaps we should add that we consider there are certain ambiguities in the author's calculations, but that the author has carefully revised his proofs.—ED.

MORE than a thousand pages would be required in order to detail the various methods of calculating reinforced concrete, published by authors or applied by engineers, and the chief interest of such a compilation would be of historical character. From the practical point of view, empirical formulæ, and purely scientific methods as well, may be eliminated, because every designer's up-to-date knowledge of reinforced concrete theory is a reason for loss of confidence in the first, whilst the general state of knowledge in the present day does not allow the actual application of the latter.

There are a great many rational methods of computation, differing, on one hand principally in symbols, algebraical forms and constants or coefficients, and on the other in the various hypotheses assumed. But as a rule the leading differences between these asumptions concern the values of the coefficient of elasticity and of the tensile resistance of concrete. If we admit a constant value for the coefficient of elasticity within the limit of stresses corresponding to the safe loads for which the constructions are designed, and if we deny to the concrete any tensile strength, considering that resistance as *nil* in the calculations, all rational methods might be translated or transposed, and written with generally used symbols and units, so as to leave only one method for each country. As for constants alone, an official committee could establish their values with authority, and for that purpose it would take into consideration the constants recognised abroad.

A standard method of computation such as that here suggested would enable any engineer, if not to design his structures in reinforced concrete, at least to verify the scantlings of their various elements determined in a more practical manner. In other words, if the stresses of concrete and steel corresponding to the maximum estimated loads did not reach the permissible limit the designer would be able to reduce the sectional areas of those materials, as on the other hand he would have to increase them if the permissible stresses were exceeded. Of course the labour involved by calculations of this kind for members subjected to flexure is out of all proportion to the magnitude of reinforced concrete constructions, but it would not be impossible to find algebraical transformations of the standard equations infinitely more handy and giving practically the same results. The derived formulæ could be obtained by the introduction of a new condition, relating to the minimum cost of the construction, as will be shown hereafter.

EMPIRICAL FORMULÆ.

HENNEBIQUE METHOD.

What is known as the Hennebique method of calculation is extensively applied to the design of columns, slabs, and beams.

(1) *Columns.*

Let P = safe load in pounds.
C = sectional area of concrete in square inches.
R = sectional area of the longitudinal reinforcement in square inches.

Hennebique writes: $P = 344C + 13760R$

The constants 344 and 13760 are not to be considered as the true stresses allowed respectively for the concrete, and for the reinforcement, unless the ratio n of the coefficient of elasticity of steel to that of concrete could be assumed as equal to 40, and the general allowance for this value is only 15.

This formula contains two unknown quantities, C and R; we want therefore another equation, suggested by the condition of minimum cost. As this minimum requires C to be as great and R as little as possible, C is to be determined by practical considerations or arbitrarily.

Let $P = 100$ tons $= 224000$ lb.
$C = 20$ in. × 20 in. $= 400$ sq. in.

$$R = \frac{P - 344C}{13760} = \frac{224000 - 344 \times 400}{13760} = 6{\cdot}23 \text{ sq. in.}$$

Let us say 6 bars $\frac{9}{8}$ in. diameter, giving 6·24 sq. in. area.

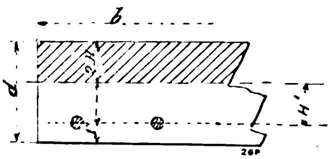
We can also employ $\frac{R}{C}$ as a percentage.

For instance, taking $\frac{R}{C} = \frac{1}{100}$, we have:

$$P = 344C + \frac{13760}{100}C = 481{\cdot}6C$$

$$C = \frac{P}{481{\cdot}6} = \frac{224000}{481{\cdot}6} = 465 \text{ sq. in.}$$

$$R = \frac{465}{100} = 4{\cdot}65 \text{ sq. in.}$$



— *Figure 1* —

Slabs.—The depth (d) of a slab being decided from constructive considerations and assumed to be equal to $2H + H' + 1$ in. (see *Fig.* 1), and M denoting the bending moment in foot-pounds per foot width, Hennebique writes:

$$\frac{M}{2} = 2H \times H \times 344$$

$$H' = d - 2H - 1 \text{ in.}$$

$$\frac{M}{2} = R \times H' \times 13760$$

Example (1).—Taking the case of a slab with the clear span of 5 ft., $d = 3$ in., and carrying a superload of 120 lb. per sq. ft., the total load is:

Super load ... ... = 120 lb. per sq. ft.
Weight of the concrete (3 × 13 lb.) ... } = 39 lb. per sq. ft.
Total load ... ... = 159 lb. per sq. ft.

If the slab is assumed to be partially built in

$$M = \frac{159 \times 5^2}{10} = 398 \text{ ft.-lb.}$$

$$\frac{M}{2} = \frac{398}{2} = 199$$

$$H = \sqrt{\frac{199}{2 \times 344}} = {\cdot}54 \text{ in.}$$

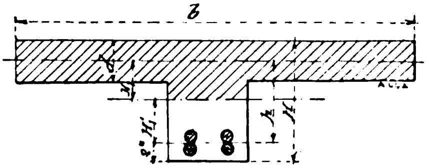
$$2H = 2 \times {\cdot}54 = 1{\cdot}08$$

$$H' = 3 - 1{\cdot}08 - 1 = {\cdot}92 \text{ in.}$$

$$R = \frac{199}{\frac{{\cdot}92}{12} \times 13760} = {\cdot}188 \text{ sq. in.}$$

Let us say for instance 4 bars ¼ in. diameter per foot run or 4 × ·049 = ·196 sq. in. area.

Beams.—Hennebique writes quite in the same way (see *Fig.* 2).



— *Figure 2.* —

$$\frac{M}{2} = db \times H_1 \times 344$$

$$H_1' = H - H_1 - \frac{d}{2} - 2 \text{ in.}$$

$$\frac{M}{2} = H_1' \times R \times 13760.$$

Example (2).—Taking the case of a beam with the clear span of 20 ft., width of the compression flange (b) = 5 ft., carrying a total load = 1000 lb. per foot run, and for which it has been decided arbitrarily that $H = 16$ in. and $d = 3$ in., we have :

$$M = \frac{1000 \times 20^2}{8} = 50000 \text{ ft.-lb.}$$

$$\frac{M}{2} = \frac{50000}{2} = 25000$$

$$H_1 = \frac{25000}{344 \times {\cdot}5 \times 3} = 4{\cdot}84 \text{ in.}$$

$$H_1' = 16 - 4{\cdot}84 - 1{\cdot}5 - 2 = 7{\cdot}66 \text{ in.}$$

$$R = \frac{25000}{\frac{7{\cdot}66}{12} \times 13760} = 2{\cdot}85 \text{ sq. in.}$$

Let us say, for instance, 2 bars $1\frac{3}{8}$ in. diameter, or $2 \times 1{\cdot}484 = 2\ 968$ sq. in. area.

Giving a mechanical significance to the Hennebique formulæ for slabs and beams, these equations would imply that the moments of resistance of the concrete in compression and of the reinforcement are equal, a condition at least quite arbitrary whilst the necessary condition of equilibrium is the equality of the resistance forces of the two flanges (the compressive and the tensile one). It is therefore evident that the constants 344 and 13760 of these formulæ cannot represent the stresses of concrete and steel.

OTHER EMPIRICAL FORMULÆ.

There are many other empirical formulæ. The author has for a long time applied the following equations for designing slabs :—

$$d = 0{\cdot}12 \sqrt{M} \quad \text{with } R = \frac{12d}{200} \text{ per foot width.}$$

the bending moment being expressed by

$$M = \frac{pl^2}{8}.$$

Example (3).—In the case taken in Example (1),

$$M = \frac{159 \times 5^2}{8} = 497{\cdot}5$$

$$d = {\cdot}12 \sqrt{497{\cdot}5} = 2{\cdot}70$$

$$R = \frac{12}{200} \times 2{\cdot}70 = {\cdot}162 \text{ sq. in.}$$

Hennebique taking $d = 3$ in. found $R = {\cdot}188$.

For the design of beams, the author has applied the equation :

$$R = \frac{M}{1390h}$$

where h is the vertical distance from centre to centre of the reinforcement in a rectangular beam with double reinforcement, or the height of the rib of a **T**-shaped beam with single reinforcement; these two lengths being approximately the same.

Example (4).—In the case considered in Example (2) where $M = 50000$ and $h = 12{\cdot}5$

$$R = \frac{50000}{1390 \times 12{\cdot}5} = 2{\cdot}88 \text{ sq. in.}$$

as compared with 2·85 sq. in. found by the Hennebique formula.

RATIONAL METHODS.

EDMOND COIGNET'S OLD METHOD.

The bases of the calculations of reinforced concrete members subjected to flexure were laid down for the first time by Ed. Coignet with the collaboration of the author in a paper read in March, 1894, before the *Société des Ingénieurs Civils de France*. That theory may be summarised as follows :—

If we neglect the existence of the concrete in tension, and if we replace the sectional area of the reinforcement by a sectional area of concrete n times as great as the first, but at the same distance from the neutral axis, we obtain a hypothetical homogeneous body which is equivalent, from the mechanical point of view, to the actual heterogeneous body, and to which we can therefore apply the usual methods relating to the calculation of homogeneous materials.

The ratio n of the modulus of elasticity of the reinforcement to that of concrete had been determinated by Ed. Coignet from scientific experiments and found to be variable according to the proportions of the ingredients, the age and, principally, the value of the compressive stress developed in concrete. The results of these experiments are detailed in the paper mentioned above, where it is shown that the mean value of the ratio n was found to be 20, for the proportions generally used in the reinforced concrete constructions, and for pressures corresponding to a factor of safety equal to 3·5. The other constants suggested by Coignet and applied at that epoch in his calculations were :

Maximum compressive stress of concrete: 550 lb. per sq. in.

Tensile stress of steel : 16,600 to 20,750 lb. per sq. in.

As explained in the same paper, the figure 20,750 is fictitious, because the reinforcement receives a very important assistance from the concrete in tension whose tensile strength was considered as *nil*, merely for the purpose of simplificating the calculations

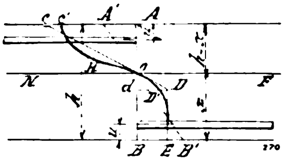
PROFESSOR RITTER'S METHOD.

In the method of Professor Ritter, adopted by the Government of Switzerland, the sectional area of the reinforcement is assumed to be replaced also by a concrete section obtained by multiplying the area of the reinforcement *n* times, *n* being equal to 10 only; but, contrary to the practice of any other author, Professor Ritter takes into account even the concrete in tension in the determination of the neutral axis. Then, knowing the position of the neutral axis, he can calculate the stresses withstood by the reinforcement and the concrete in tension or compression, and ascertain whether or not the normal tensile stress of concrete has been exceeded. If exceeded, the concrete in tension is to be assumed as broken, and therefore as the reinforcement alone has to take the whole tensile force, its stress must be increased in proportion. In that theory, the position of the neutral axis is assumed to be uninfluenced by the failure of concrete in tension, a result that occurs between 400 lb. and 550 lb. per square inch.

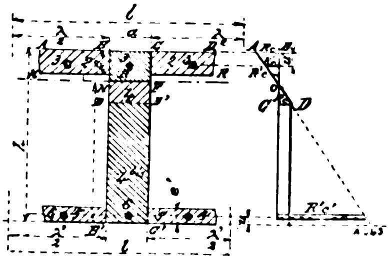
CONSIDÈRE'S METHOD.

The question of the tensional resistance of plain as well as of reinforced concrete has been thoroughly investigated by M. Considère, *Inspecteur Général des Ponts et Chaussées*. From several series of experiments Considère drew the conclusion that reinforced concrete is capable of elongations 20 times as great as those causing the rupture of plain concrete, if the limit of elasticity of the reinforcement had not been exceeded. As long as reinforced concrete does not bear tensile stresses or suffer elongations greater than those it is able without breaking when plain, its modulus of elasticity remains sensibly constant, and the stresses therefore increase proportionately to the elongation; that is the limit of elasticity of all elements constituting the reinforced concrete. When the deformation exceeds that limit, the elongation of concrete increases more and more with practically no increase of tensile stress, so that the modulus of elasticity is reduced almost to zero.

The real stress strain curve of compression and tension being C'OD'E (*Fig.* 3), M. Considère substitutes for it without appreciable error the straight lines CODE, in order to simplify the determination of the neutral axis, and therefore the relations between the external and internal forces.



— Figure 3 —



— Figure 4. —

The full development of Considère's theory is to be found in a treatise by the author[1] for the most general case (*Fig.* 4).

Let h = total height of the member.

(h may be taken as the unit of height.)

x and $(h - x)$ = the distance of the neutral axis NF from the extreme fibres at the bottom and top respectively.

u and u' = the distances of the reinforcement from the extreme fibres at the bottom and top respectively.

e and e' = the depths of the compressed and of the extended flange.

E_s and E_c = the modu of elasticity of steel and of concrete.

$n = \frac{E_s}{E_c}$ = the ratio of the first modulus to the second.

R_s = the unit stress of the reinforcement in tension.

R_s' = the unit stress of the reinforcement in compression.

f = the total sectional area of the reinforcement in tension.

f' = the total sectional area of the reinforcement in compression.

a = the breadth of the rib.

R_t = the maximum unit stress of the concrete in tension.

---

[1] Traité theorique et pratique de la Résistance des Materiaux appliqué au béton et au ciment armé. N. de Tedesco et A. Maurel.

R_c = the maximum unit stress of the concrete in compression.

R'_c = the minimum unit stress of the concrete in compression in the slab.

R_c' = the unit stress of the concrete at the distance u' of ABCD.

l and l' the width of the slabs or flanges working with the rib.

λ or λ' = the ratio $\frac{l-a}{a}$ or $\frac{l'-a}{a}$

Determination of the neutral axis.—The neutral axis NF divides the section into two parts, one subjected to compression, the other to tension. The condition of equilibrium requires first that the sum of the compressive stresses shall be equal to the sum of the tensile stresses. In order to calculate these forces we have to multiply the sectional area of every geometrical element of the cross section by its average unit stress.

Let us apply this rule to the most general case of a **I**-shaped member (see *Fig.* 4).

(1) *Compression area of the rib.*—Breadth $= a$; height $= h - x$; sectional area $= a(h - x)$; average unit stress $= \frac{R_c}{2}$; compressive strength $= \frac{aR_c}{2}(h - x)$.

(2) *Compression slab.*—Breadth $= \lambda$; depth $= e$; sectional area $e\lambda$; average unit stress (see trapezium ABKR $= \frac{R_c + R'_c}{2}$; R'_c may be determined if we assume the cross sections remain plane surfaces during loading. Therefore, $R'_c = R_c \frac{h - x - e}{h - x}$; whence $e\lambda \frac{R_c + R'_c}{2}$ $= \frac{e\lambda}{2} R_c \frac{eh - ex - c}{h - x}$

(3) *Reinforcement in compression.* — Sectional area $= f'$ is to be replaced by a concrete area $= nf'$; average unit stress Rc' can be determined according to the hypothesis of conservation of sections, as $R_c \frac{(h - x - u')}{h - x}$. Then . . . $nR_c f' \frac{h - x - u'}{h - x}$

(4) *Tension area of the rib.*—NFDD' from the neutral axis to DD', the limit of extension of plain concrete; height $= \frac{R_t}{R_c}(h - x)$; breadth $= a$; sectional area $a \times \frac{R_t}{R_c}(h - x)$; average unit stress $\frac{R_t}{2}$. Then . . . . . $\frac{R_t}{2R_c} a (h - x)$

(4 bis) *Tension area of the rib.*—DD'B'C' from the limit mark DD' to the extreme fibre B'C'; height $= x - \frac{R_t}{R_c}(h - x)$; breadth $= a$; constant unit stress $= Rt$.

Then . . . . $aR_t\left[x - \frac{R_t}{R_c}(h - x)\right]$

(5) *Tension slab.* — Breadth $= \lambda'$; depth $= e'$; sectional area $= e'\lambda'$; constant unit stress $= R_t$. Then . . . . . . $R_t \times e'\lambda'$

(6) *Reinforcement in tension.*—Total sectional area f is to be replaced by a concrete area $= nf$; average unit stress $R'_c = Rc \frac{x - u}{h}$

Then . . . . $nf \times \frac{x - u}{h - x} R_c$

The equation expressing the sum of the stresses 1, 2 and 3 = sum of stresses (4, 4 bis, 5 and 6), allows the determination of x; that is the position of the neutral axis.

Determination of the moments of resistance.—The total moment of resistance of the member may be obtained by multiplying every stress above calculated into its arm of leverage, or the distance of its point of application from the neutral axis.

These arms of leverage are respectively :

(1) $\frac{2}{3}(h - x)$

(2) See the centre of gravity O of the trapezium ABA'B'

$$\frac{2}{3}(h - x)\frac{3h - 3x - 3e + \frac{e^2}{h - x}}{2h - 2x - e}$$

(3) $h - x - u'$

(4) $\frac{2}{3}\frac{R_t}{R_c}(h - x)$

(4 *bis*) $\frac{R_t}{2R_c}(h - x) + \frac{x}{2}$

(5) $x - \frac{e'}{2}$

(6) $x - u$

All these various expressions are true whatever may be the position of the neutral axis, even if this latter falls inside the compression slab. These equations may be applied algebraically to any case as demonstrated in the treatise mentioned above.

But having stated that as a rule the value R_t is to be assumed as *nil*, we have to neglect every term containing R_t; so that the two equations become :

$$\frac{aR_c}{2}(h - x) + \frac{e\lambda}{2} R_c \frac{2h - 2x - e}{h - x} + nR_c f' \frac{h - x - u'}{h - x} = nf \frac{x - u}{h - x} R_c,$$

and

$$\mathrm{M} = \frac{a}{3}(h - x)^2 \mathrm{R_c} + \frac{e\lambda}{3}\mathrm{R_c}\left[\frac{e^2}{h - x} + 3(h - x - c)\right] + nf\mathrm{R_c}\frac{(h - x - u')^2}{h - x} + nf\mathrm{R_c}\frac{(x - u)^2}{h - x}.$$

APPLICATIONS.

Let us apply these equations to a slab reinforced only to resist compression.

$$\lambda = 0\,;\ f' = 0.$$

(1) $$\frac{a\mathrm{R_c}}{2}(h - x) = nf'\frac{x - u}{h - x}\mathrm{R_c}$$

(2) $$\mathrm{M} = \frac{a}{3}(h - x)^2\mathrm{R_c} + nf'\mathrm{R_c}\frac{(x - u)^2}{h - x}$$

Let a = unit length ; $n = 15$.

(1) $$\frac{h - x}{2} = 15f\frac{x - u}{h - x}$$

(2) $$\mathrm{M} = \mathrm{R_c}\left[\frac{(h - x)^2}{3} + 15f\frac{(x - u)^2}{h - x}\right].$$

Adding a new equation given by the hypothesis of conservation of plane sections

(3) $$\mathrm{R_s} = n\mathrm{R_c}\frac{x - u}{h - x}$$

we see that we have only 3 equations and 6 unknown quantities, $\mathrm{R_s}$, $\mathrm{R_c}$, h, f, u and x ; 2 quantities are known $n = 15$ and M = the bending moment.

But, such as they are, these equations can be employed for verifying the proportions of a member already designed, as follows :—

Taking the slab, designed as in Example I by an empirical method, the bending moment is M = 398 foot-pounds per foot, or inch-pounds per inch; $h = 3$ in.; $u = 1$ in. and $f = {\cdot}188$ sq. in. per foot, or $\frac{\cdot 188}{12} = {\cdot}0157$ sq. in. per inch.

(1) $$\frac{3 - x}{2} = 15 \times {\cdot}0147\frac{x - 1}{3 - x}$$

$$x^2 - 6{\cdot}44x + 9{\cdot}44 = 0$$

$$x = 3{\cdot}22 - \sqrt{\overline{3{\cdot}22}^2 - 9{\cdot}44}$$

$$x = 2{\cdot}26\,;\ h - x = {\cdot}74\,;\ x - u = 1{\cdot}26$$

(2) $$398 = \mathrm{Rc}\left[\frac{\overline{\cdot 74}^2}{3} + 15 \times {\cdot}0147\frac{\overline{1{\cdot}26}^2}{\cdot 74}\right]$$

$$\mathrm{Rc} = \frac{398}{\cdot 653} = 610 \text{ lb. per sq. in.}$$

(3) $$\mathrm{R_s} = 15 \times 610 \times \frac{1{\cdot}26}{\cdot 74} = 15580 \text{ lb. sq. in.}$$

Applying the equations (1) and (2) to a **T**-beam, with single reinforcement, that is for $f' = 0$

(1) $$\frac{a\mathrm{Rc}}{2}(h - x) + \frac{e\lambda}{2}\mathrm{R_c}\frac{2h - 2x - c}{h - x} = nf\frac{x - u}{h - x}\mathrm{R_c}$$

(2) $$\mathrm{M} = \frac{a}{3}(h - x)^2\mathrm{Rc} + \frac{e\lambda}{3}\mathrm{R_c}\left[\frac{e^2}{h - x} + 3(h - x - e)\right] + nf\mathrm{R_c}\frac{(x - u)^2}{h - x}$$

And for the **T**-beam in Example 2, for which we got : M = 50000 foot-pounds per foot (or inch-pounds per inch).

$\mathrm{H} = 16''$; $e = 3''$; $u = 2''$; $n = 15$;

$$f = \frac{2{\cdot}85}{12} = {\cdot}238 \text{ sq. in. per inch.}$$

$$\lambda = \frac{l}{a} = \frac{16 - a}{a} \text{ and assuming } a = 7\text{in.}$$

$$\lambda = \frac{16 - 7}{7} = 1{\cdot}29$$

(1) $$\tfrac{7}{2}(16 - x) + \frac{3 \times 1{\cdot}29}{2} \times \frac{2 \times 16 - 2x - 3}{16 - x} = 15 \times {\cdot}238\frac{x - 2}{16 - x}$$

(2) $$\frac{\mathrm{M}}{\mathrm{R_c}} = \tfrac{7}{3}(16 - x)^2 + \frac{3 \times 1{\cdot}29}{3} \times \left[\frac{3^2}{16 - x} + 3(16 - x - 3)\right] + 15 \times {\cdot}238\frac{(x - 2)^2}{16 - x}$$

The equation (1) can be written :

$$x^2 - 34{\cdot}12\,x + 274{\cdot}07 = 0$$

$$x = 12{\cdot}94$$

$$h - x = 16 - 12{\cdot}94 = 3{\cdot}06$$

$$h - x - e = 16 - 12{\cdot}94 - 3 = {\cdot}06$$

$$x - u = 12{\cdot}94 - 2 = 10{\cdot}94$$

Substituting the value of x, found above in the equation (2)

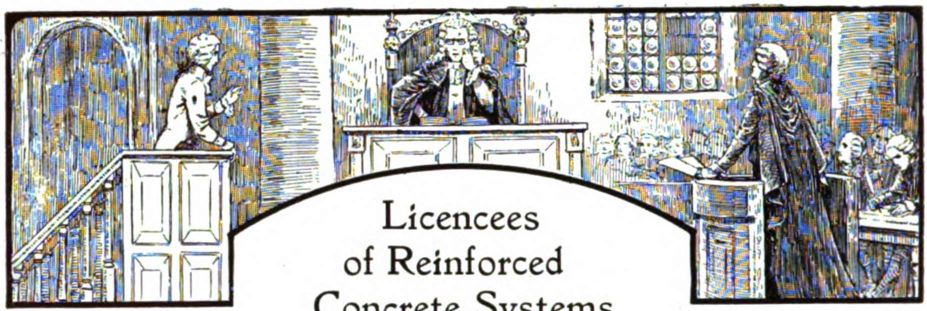
(2) $$\frac{\mathrm{M}}{\mathrm{R_c}} = \frac{3{\cdot}06^2 \times 7}{3} + \frac{1{\cdot}29 \times 3}{3}\left[\frac{\overline{3}^2}{3{\cdot}06} + 3 \times 0.06\right] + 15 \times {\cdot}238 \times \frac{\overline{10.94}^2}{3.06}$$

$$\frac{\mathrm{M}}{\mathrm{R_c}} = 21{\cdot}85 + 4{\cdot}02 + 139{\cdot}63 = 165{\cdot}50$$

$$\mathrm{R_c} = \frac{50000}{165{\cdot}50} = 302 \text{ lb. per sq. in.}$$

$$\mathrm{R_s} = 302 \times 15 \times \frac{10{\cdot}94}{3{\cdot}06} = 16{,}200 \text{ lb. per sq. in.}$$

Thus we see that empirical formulæ give suitable, if not always accurate results, but they do not enable us to calculate the unit stresses of the material, as can be done by rational equations. Unfortunately the latter are by no means handy for ordinary calculations, or for the expeditious design of reinforced concrete buildings.



Licencees of Reinforced Concrete Systems

The Limitations of their general business as Contractors.

MOUCHEL v. WILLIAM CUBITT & CO.[*]

In a journal of this description important law cases must necessarily be dealt with from time to time. In this instance we are presenting a case on the question of a licence granted with certain limitations. Our view of the case is expressed in our Editorial Notes, and we can only repeat that it appears extraordinary that numerous eminent firms of contractors should actually limit themselves in the execution of reinforced concrete work by covenanting not to carry out work that might be in competition with any one particular system of design. If, upon appeal, the contractor in question and other contractors are found to have tied their hands, as shown in the decision given in this case, we fear they have only themselves to blame in not realising the conditions of their so-called licence, and no matter how correct the legal facts may be, it is certainly a technical anomaly, detrimental to the development of reinforced concrete in this country, that first-class contractors should be precluded from carrying out reinforced concrete works other than those on specialist designs.—ED.

THIS case was tried before Mr. Justice Neville early in February. Mr. Upjohn, K.C., and Mr. F. Newbolt appeared for the plaintiff, and Mr. Astbury, K.C., and Mr. P. Wheeler appeared for the defendants.

The plaintiff, as agent in the United Kingdom for Mons. F. Hennebique, brought the action against the defendants for an injunction and damages for breach of the terms contained in and said to be implied by a licence granted by the plaintiff to the defendants in March, 1903, to work the Hennebique British Patents Nos. 10203, 30143, and 30144 of 1897.

The licence granted to the Licensees a licence to use the inventions within the "Town of London in the County of ——" for the residue of the terms for which the patents were granted and any extension thereof. The royalty reserved was 12 per cent. on the gross price of the contracts secured by the Licensees.

Clause 3 read:—

> The Licensee will not enter into any contract as aforesaid without having previously furnished to the Licensor all such details, plans, sections, elevations, and information as he may reasonably require relating to the proposed contract or without having previously obtained the approval of the Licensor to the preliminary plans of the proposed constructions, and, further, the Licensee, upon entering into any such contract, will forthwith inform the Licensor thereof, and thereupon the Licensor will furnish to the Licensee all necessary working plans in connection therewith and in accordance with the preliminary plans, and the Licensee shall carry out every such contract in strict accordance with such working plans in every detail. And the said F. Hennebique or the Licensor, respectively, shall be only responsible to the Licensee for such working plans or calculations as shall be signed or initialled by them or either of them respectively, and such responsibility shall continue until the work has been properly tested after completion, in the presence of the persons respectively responsible and no longer.

The Licensor reserved the right to grant 24 similar licences in the same district, and also the right to contract with the Licensees or anyone else for all work for the Government or for Dock, Railway, and Harbour companies or authorities.

---

[*] Reported by Douglas Leechman, Esqr., A.I.M.E., Barrister-at-Law.

Clauses 11 and 12 were as follows:—

> 11. The Licensee undertakes to keep the Licensor fully informed of all new work in his district suitable for the Hennebique system, and, further, will use his best endeavours to detect every suspected infringement of the said letters patent within the said district and will give the Licensor written notice thereof forthwith and will, at the expense of the Licensor as to actual disbursements (if any) made or liabilities incurred thereby, assist him or the said F. Hennebique in any proceedings in respect of such infringement as shall be reasonably required.
>
> 12. The Licensee will not at any time, without the written consent of the Licensor, carry out or contract to carry out any ferro-concrete or other similar work which may be an infringement of the said patents ***or be in competition with the same.*** (The italics are ours.—Ed.)

The licence appears to have been unskilfully drawn and accepted without professional assistance.

It was expressed in such a way as only to be determinable at the option of the Licensor, in certain events.

More particularly the plaintiff alleged breaches of Clauses 11 and 12. He also maintained, in paragraph 4 of his Statement of Claim, that it was an implied term of the said licence that the defendant should loyally co-operate with the plaintiff to extend and promote the success of the said Hennebique system, and should not assist, promote or advise any rival or competitive system of ferro-concrete construction in the United Kingdom, or in the alternative in the London district.

On the other hand, the defendants maintained that Clause 11 was too vague to be carried out more fully than they had carried it out; and as to Clause 12, they had only constructed (at Whitbread's Brewery) a small piece of reinforced concrete on a system which was in competition with, but not within, the Hennibique patents, for the purpose of raising the question as to what was a proper construction of the clause.

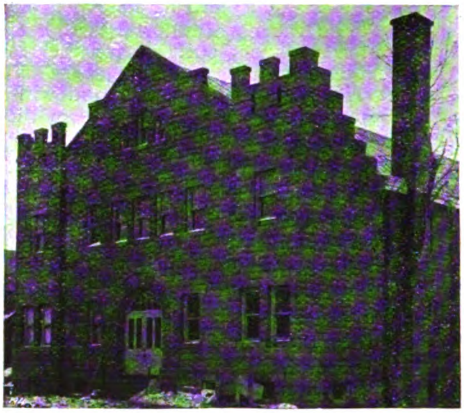
The defendants contended that this Clause 12 was wider than was reasonably necessary to protect the plaintiffs, and, indeed, that it was so wide as to be void, because injurious to the public interest and a restraint upon the defendants' trade.

The defendants sought relief on the ground that the position was analagous to that of the sale of a business, where the purchaser was unreasonable in restricting the area and the time within which the vendor might set up in competition. The restrictions were oppressive, and if oppressive they were unreasonable and void.

The defendants also denied that any such covenant as that sought to be set up by the plaintiff's Statement of Claim was implied by the licence; and in this they were successful. But after hearing Counsel, his Lordship gave judgment for the plaintiff, restraining defendants, their servants, agents, and workmen from carrying out or contracting to carry out, without the written consent of the plaintiff, any ferro-concrete or other similar work which may be in competition with the Hennebique system of ferro-concrete construction under the patents mentioned in the Statement of Claim.

The case is referred to an Official Referee for an inquiry as to the damages which the plaintiff has sustained by the defendant's breach of Clause 12 of the licence; and, the defendants denying that there has been any breach of this Clause, except in respect of Whitbred's building, all costs of the inquiry are reserved. The defendants are to pay the costs of the action, except in so far as they have been increased by paragraph 4 of the Statement of Claim, which latter part of the costs are to be paid by the plaintiff and set off.

ARTIFICIAL STONES.



So many enquiries reach us as to the artificial stones available, and their component parts that we herewith present some general information, together with particulars of some of those well known on building and engineering works.

In publishing this article, we wish to mention that the necessary data were prepared in part by Mr. Phillip S. Fletcher, F.R.I.B.A., and in part by Mr. Frederic R. Farrow, F.R.I.B.A., but that in the main the information courteously given by the various makers had to be relied upon for these data.—ED.

MATURED NATURAL STONE.

A great difficulty in the architectural profession in recent years has been the selection of a hard natural stone at a moderate cost. It is not possible nowadays to obtain the Whitbed of Portland stone, and one has to be content with the inferior brown bed of this stone.

HARD ARTIFICIAL STONE.

To meet this difficulty many manufacturers and others have endeavoured, by the use of waste chippings and cement, to produce an artificial stone that would take the place of a hard natural stone.

Processes have been invented which claim to produce a material that will not only withstand the various atmospheric influences, but will also sustain considerable weight and stress. But no means have yet been discovered which can give us a stone to compare with the fine appearance of the old weathered Portland, although the artificial stones at present on the market are a vast improvement upon the results of earlier efforts.

The modern tendency to return to the old Roman method of concrete construction has recently given a fillip to the use of artificial stone. Architects very naturally dislike to use this material externally, and, indeed, not much economy is gained by its use, unless there is a considerable replication of mouldings and ornamentation that can be turned out by the moulds at the works. In plain work, therefore, artificial stone cannot always be very economically used, but the use of this material for paving and internal construction is largely on the increase.

There are at the present time many excellent artificial stones on the market, some of which we will discuss in detail. Although many attempts have been made, with more or less success, to produce artificial stones by synthesis of chemical reagents, those in use at the present day are merely concrete in one form or another, and the lessons that experience has taught in the use of concrete have been recognised in the manufacture of artificial stone.

CONCRETE.

This may be defined as an artificial compound made by mixing a cementing material, or matrix, and some hard material, or aggregate, such as sand and broken stone, gravel, brick, slag, broken clinkers, or Thames ballast. All these ingredients must be well mixed so as to form a close conglomerate free from voids, so that the result is a species of rough rubble masonry, and might be legitimately classed under the heading of artificial stone.

In the selection of an aggregate, materials of an angular and porous nature are preferable, owing to the fact that the cementing material will adhere more readily to their rough surfaces, whilst the angular pieces form a kind of rough bond.

When it is desired to keep down the weight of the concrete, coke breeze is frequently used for the aggregate, and this material also possesses the advantage that nails can be driven into it without the insertion of wooden plugs. All aggregates should be broken to pass through a sieve having a mesh of one and a-half to two inches.

With regard to the use of slag as an aggregate, that from iron furnaces has at times too polished a surface to make a good concrete, but if the surface is porous it is to be recommended. It is hard, heavy, and of great strength, which latter characteristic is due to the fact that the iron combines with the matrix chemically, making it harder than it would otherwise be; but if the slag contains lime it may be imprudent to use it unless care be taken that the constituents exist in the proper proportion.

The results of experiments as to the relative value of some of the many aggregates in use are given in the proceedings of the Institute of Civil Engineers, Vol. XXXII., as under :—

Blocks 12 inches Cube (Compressed).

Composed of one part Portland cement to eight parts of aggregate.

Materials for Aggregate.	Crushing strength in tons. *Blocks in air.*	*Blocks in water.*
Ballast	61	76
Portland Stone	110	126
Gravel	74	85
Pottery	97	118
Slag	85	70
Flints	103	117
Glass	65	94

Experiments show that compressed blocks are stronger than uncompressed blocks in greater proportion than their density.

It will be seen that concrete made from pottery was stronger than that made from gravel, which emphasises our previous observations relating to the desirable properties of an aggregate.

The strength and other qualities of concrete depend to a large extent upon the matrix, and the cements used for this are calcareous substances resembling to some extent the hydraulic limes, but the hydraulicity (or power of setting under water) is much greater.

1. Natural Cements.
2. Artificial Cements

1. Natural Cements are obtained by calcining limestones containing a considerable amount of clay, but their use in this country is now almost confined to Belgian manufactures fraudulently sold as " Portland Cement."

2. Artificial Cements. Hydraulic cement is made by a process very similar to that for preparing artificial hydraulic lime, the main difference being that a higher

proportion of clay is added and it is calcined at a very high temperature, which causes incipient vitrification.

It must be noted that to get a satisfactory result the ingredients must be carefully selected and intimately mixed, all under-burnt portions must be thrown out, and the resultant clinker must be very finely ground.

PORTLAND CEMENT.

This cement, originally so called from a somewhat doubtful similarity in colour to Portland stone, is to-day the most important and paramount representative of artificial hydraulic cements, as, although it takes longer to set than some of the other varieties, it attains a greater ultimate strength. We will now consider briefly the question of hydraulicity in cements.

HYDRAULICITY.

The first serious attempt to discover the cause which enabled certain limes to set under water was made in 1756 by John Smeaton when engaged in the construction of the Eddystone Lighthouse, where it was necessary for a cement to be used which was capable of setting quickly under water, and for that reason a series of experiments were carried out. The old theory that the harder the stone the better the lime, was found to be only correct so far as that the hardest stones were best for certain uses when exposed to the atmosphere, but whether obtained from the hardest marble or softest chalk, such limes were in many instances found to be practically valueless when used under water. It was found that limes which would set quickly under water were obtained from the calcination of such limestones as contained a large proportion of clay in their composition. It was for this reason that a compound of the lias lime from Aberthaw and of puzzolana, brought from Civita Vecchia, near Rome, was used, and at the present day no better material could be mixed for this purpose; but the price prevents its extensive use.

Apparently the only treatment of pure calcareous lime after burning that makes it more inclined to set in water is an admixture of trass puzzolana or other ferruginous substance. Many authorities have attributed the hydraulicity of lime to the presence or iron oxide, and others—Guyton de Morveau and Bergmann—to the presence of oxide ot manganese.

ARTIFICIAL HYDRAULIC LIMES.

These are not very largely manufactured in Great Britain, but they may be made by slightly calcining an intimate mixture of fat lime with as much clay as will give the mixture a composition of a similar nature to that of a good natural hydraulic limestone. A soft material like chalk can be powdered and mixed with clay in the raw state.

Compact limestone is more commonly burnt and slaked in the first instance, this being considered the most economical way of reducing it to powder; it is then mixed with the clay and burnt a second time. This is called *twice kilned lime.* Another method which is sometimes used is to violently agitate the materials together by machinery in water; or, when in a dry state, by grinding them together, afterwards adding water to form a paste. The latter is then made into bricks, which are dried, calcined and otherwise treated like ordinary lime.

TESTING CEMENTS.

In using Portland cement for special work, it is important to test it beforehand, and the cement should at least comply with the requirements and tests described in the "British Standard Specification for Portland Cement" prepared by the Engineering Standards Committee.

A simple practical test without machines is to make small blocks 1 in. square and

8 ins. long, immerse in water for seven days, then place on supports 6 ins. apart, and they should stand the transverse strain of 75 lbs. placed at the centre.

METHODS OF TESTING.

Owing to the fact that tests of Portland cements made at the Royal Testing Laboratory gave results of a less satisfactory nature than those of the manufacturers themselves, an investigation was made in order to show how the methods of testing affected the results, and from certain extracts from a paper read by M. Gary at the Institution of Civil Engineers (*vide* M.P.C.E., Vol. CXXXIV.), the following conclusions were drawn, having regard to (1) The mixing of mortar, (2) making Test Specimens, (3) removal of Test Specimens from Moulds, and (4) Hardening of Test Specimens.

The Mixing of Mortar.

(1) If mortar be mixed in the proportion of 3 parts of sand and 1 part of cement, the quantity mixed, up to 9 lbs., does not influence the strength of the specimens. This applies when mixing is continued for three minutes, but it was found that if a longer time was taken, the strength of the specimen would be slightly reduced, and that a small quantity of water gave a high tenacity.

In these experiments five different kinds of mixing were tried. The highest tenacities were given with Steinbruck's Mortar Mixer, the revolutions of the mixing arms being 25 per minute. With trowel mixing the particles of sand were reduced in size to no appreciable extent, whilst with the ball mixer a considerable reduction took place.

It was found that the difference in size in the particles of sand has practically no influence on the strength of the specimens, but the sand should be well washed and should on no account contain more than ·09 per cent. soluble matter. As a result of these experiments, it was pointed out that normal sand should be taken from the same sandpit and be always under control. The "Standard" sand now used for testing with cement is obtained from Leighton Buzzard.

MAKING TEST SPECIMENS.

(2) Oil of low vicosity should be used for greasing the moulds, and the quantity of material accurately weighed.

The difficulty of preparing neat cement cubes of uniform density is considerable, and it was found that the greatest strength was obtained with 150 strokes of a 4½ lb. hammer.

High speed of the hammer lowers the tenacity but raises the compressive strength; a standard speed should be used of 50 strokes per second.

Removal of Test Specimens from the Moulds.

(3) To get satisfactory and trustworthy results, tension and pressure specimens are carefully smoothed off on the upper surface, and the specimens should be kept in the moulds for tension 30 minutes, and for pressure 24 hours.

Hardening of the Test Specimens.

(4) Specimens should be hardened in still water, which should be changed every eight days. Slow setting cements should be protected from vibration, as this delays hardening. Freshly-made specimens should not be subject to draughts.

In comparative tests of Portland cement the water in which the specimens are hardened should be kept at uniform temperature. The strength of specimens hardened in warm water was found to be greater than of those hardened in cold.

Having considered the composition of concrete, we will now deal with the various forms in which it is used as a substitute for natural stone.

ARTIFICIAL STONES.

1. Ransome's Stone. One of the best known artificial stones was that prepared originally by the late Mr. F. Ransome. It was made by mixing artificially-dried sand with silicate of soda, which is nothing more than dissolved flint, and a small portion of stone or chalk. These were thoroughly incorporated in a pug mill and the mixture was then forced into moulds by hand.

When the blocks were turned out a solution of cold calcium chloride was poured over them; they were then immersed in a boiling solution of the same material. In the very best quality the solution was applied under pressure, thus hardening the stone. The excess of sodium chloride, which would cause efilorescences if left, was washed off, but was not always completely removed and efflorescence frequently resulted.

The success of the above process was due to the double decomposition of the silicate of soda and chloride of calcium; the chlorine and soda combining to form sodium chloride, or common "salt," which was supposed to be washed out and the silica combining with the calcium produced silicate of lime which bound the particles of stone together.

With regard to the characteristics of this stone, its texture is uniform and its mass homogeneous. It can be used for enrichments owing to the facility with which it can be moulded. Its absorbtion of water from immersion of its weight is about 6 per cent. in 24 hours. Its tensile strength is about 360 lbs. per in., it has a crushing resistance of 2 tons per in., and its weight is 120 lbs. per cubic ft. These figures are given as approximately correct, but of course age and the selection of the ingredients will slightly alter the data.

This stone is one of the best examples of the synthetic chemical process of manufacturing artificial stone. The power of resisting atmospheric influences is, of course, a very important factor, and it was found by Prof. Frankland that the weathering properties and resistance to acids of Ransome's stone compared favourably with that of the best Portland Parkspring and other good natural stones. It is claimed that it can be used for all cases in which natural sand and limestones are required; but the economy is chiefly found, as previously mentioned, in dressings and repetition mouldings. It may also be used in hollow blocks for foundations, grindstones, etc., and by substituting corundum and oxide of iron for the sand, solid emery is produced, useful for polishing metal surfaces.

2. Apoenite. This stone is of a similar composition to Ransome's, but is made with five parts of sand, one Farnham Rock, 1¼ Portland Cement and the same proportion of silicate of soda. The advantage of its use as compared with Ransome's is claimed to be that it is more easily produced and can be made on the site.

Its weight is approximately 137 lbs. per cubic ft., and it absorbs 5½ per cent. of its weight of water in 24 hours.

3. Empire Stone. This stone is one which should be classed under the heading of hardened concrete. The manufacture is very similar to most of the other artificial stones, and this particular stone appears to weather well under most atmospherical conditions. It is made from finely ground and well-washed granite and the best Portland cement well mixed by machinery. The manufacture requires five weeks from the date of order to the date of delivery. It varies from most of the others simply in finish.

The Empire stone is tanked directly it is made and kept in water until it is required for use.

The price is about 5s. per ft. cube delivered. It is particularly adapted for enrichments, which may be carved on the site, and all architectural decoration, and it has been extensively employed. It differs from Victoria stone chiefly in the fact that it is tanked directly it is made and kept in water until it is required. It is made in various colours and can be matched with Portland, Red and Yellow Mansfield, and is extensively used for paving purposes, the price of the latter being approximately from 3s. 10d. to 4s. 6d. per yard superficial fixed. The slabs are from 2 ins. to 2½ ins. in thickness.

4. Victoria Stone. This well-known stone consists of finely powdered and washed Leicestershire granite and the strongest Portland cement, "Gibbs" Brand. It is hardened by immersion in silicate of soda, which is formed by boiling ground Farnham stone in caustic soda. A mixture of four parts of crushed granite and one of Portland cement is left to set for about three days into a hard block shaped to any requirements by means of a mould, it is then immersed in silicate of soda for eight or nine weeks.

The granite used is from Groby in Leicestershire and is washed by patent machinery. When tested in 1863 by Kirkcaldy this granite was found to withstand a crushing strain of 20,742 lbs. per sq. in., and under the same experiments it was found that Guernsey granite stood a pressure of only 15,062 lbs. per sq. in. The granite used in the aggregate is found to have the following analysis:—

Silica (soluble)	0·55
Silica (insoluble)	65·26
Alumina	13·06
Lime	4·55
Magnesia	1·01
Oxide of Iron	9·81
Carbonic acid	0·03
Soda	2·34
Potash	2·85
Water, etc.	0·54
	100·00

It is worthy of note that Leicestershire granites show, upon analysis, that they are unusually free from alkaline ingredients.

With regard to the tests for the Portland cements used in the manufacture of this stone it will suffice to say that it is made into briquettes, with a breaking surface of one sq. in. The briquettes are exposed for 24 hours and then immersed in water for six days. They are then tested by a double lever testing machine to about 1,300 lbs.

The slabs when hardened are stacked in the yard to season and are sent away in order of age, and it would appear to be in this respect that the chief difference exists between its manufacture and that of the Empire stones. The analysis of a piece of Victoria paving slab is as below:—

Silica	50·35
Alumina	11·87
Lime	18·33
Oxide of Iron	7·33
Magnesia	2·03
Potash	1·78
Soda	3·81
Carbonic acid	1·80
Water, etc.	2·70
	100·00

It is claimed that the Victoria stone has a resistance to crushing of 535 tons per sq. ft., which is the result of experiments by Kirkcaldy. This compares very favourably with the following stones and bricks:—

	Per sq. ft. Tons.
Portland Stone (Whitbed), Beare's Experiment	205
Peterhead Granite, Beare's Experiment	1,208
Bramley Fall, Grant's Experiment	338
Staffordshire Blue Brick, Unwin's Experiment	425
Craigleith Stone, Beare's Experiment	362
Pressed Medway Gault Brick, Grant's Experiment (average)	170
Roache Abbey Magnesia Limestone, Commissioners on Stone	250
Bath Oolite (Box ground), Beare's Experiment	82-126

The tensile strength in 1879 was 794 lbs. per sq. in., but as at present manufactured it has a tensile strength of 1,310 lbs. per sq. in. This stone is used largely for paving, as it is cheaper and stands more crushing force than Yorkshire flags. It is also used for sills, copings, pier caps, stairs, landings, etc. Its weight is from 140 to 160 lbs. per cubic ft., and its absorption is from 2 to 6 per cent. of its weight of water in 24 hours.

It is claimed for Victoria stone that in appearance it has a close approximation to natural stone, and it is supposed to be equal in colour to Portland, and more homogeneous, but no artificial stone that we know of is entirely free from an artificial appearance. This stone does not become slippery, nor does it become laminated by wear.

The price compares favourably with that of the best quality Bath stone.

5. Silicated Stone. This stone is made in almost exactly the same way as that last mentioned. Its composition consists of granite dust mixed with Portland cement and made into a paste, cast, dried and then immersed in a silicate of an alkali in order to harden it and give it a face which will weather. It is chiefly used for pipes and paving.

6. The Engratic Stone is very similar to Victoria stone, but no solution is used. This stone is employed chiefly for dressings, copings, steps, paving, etc., owing to the fact that it does not become slippery by use. The prices are approximately:—Moulded work, 3s. 6d. per ft. cube; Paving, 2″ 3s. 6d.; 1½″ 3s.; 1″ 2s. 6d. per ft. super.

7. Imperial Stone is also very similar to Victoria stone, the aggregate being finely crushed and well-washed Leicestershire granite. It is used extensively for pavings and steps and also for dressings in buildings, and the cost is approximately 2s. 6d. per ft. run for steps, etc., and about 4s. 6d. per ft. cube for plain work in buildings. Kirkcaldy found the crushing weight of this stone to be 9,492 lbs. per sq. in., which is 25 per cent. higher than that of any natural stone.

This material is also used for pipes, which are stronger than those manufactured from glazed stoneware. It would require an impact of about 161 lbs. to break a silicated stone pipe, whereas an impact of 75 lbs. would be sufficient to break most stoneware pipes. These pipes are true in section, which is of great importance in sewer work, and are capable of withstanding the vibration of heavy traffic to a greater extent than earthenware.

8. The Beacon Stone. This stone is made from finely-ground Portland stone, instead of granite chippings, and has a granular face. It can be made in various colours to match almost anything, the colour going right through the block. It is particularly used for non-slipping stair-treads and risers. The cost is approximately from 3s. to 4s. per ft. cube.

9. Excelsior Patent Stone. This stone is made with clean-washed Leicestershire granite chippings and best Portland cement, and is used in large quantities for sills, copings, staircases, paving and all architectural dressings. It is homogenous throughout and is not faced. It is of great strength, good appearance and low in price. This stone does not become slippery through vegetation, etc., neither is it laminated by wear, and it absorbs but little moisture, its porosity being but 1 per cent. after four hours' immersion.

The crushing weight is 9,400 lbs. per sq. in. The tensile strength is 1,300 lbs. per sq. in. It is not affected by heat or cold; weathers well, and resembles in colour a blue York stone.

This material is made up into stone flooring, tiles, flags, sills, saddle copings, kerbing, paving, setts for crossings, landings, staircases, etc. The prices are aproximately as follows:—Steps, per ft. super., 9d. to 1s. 7d.; sills, moulded heads, 11d. to 1s. 4d., in lengths to suit usual openings; paving, 1 in. to 2½ ins. thick, 2s. 6d. to 4s. 6d. per yd.

10. Stuart's Granolithic. This material resembles most other artificial stones in the fact that it is simply finely-ground granite chippings from Aberdeen and Dalbeattie, and the cement is specially prepared for the company. It was at one time extensively used for paving, although that particular industry, as far as private firms are concerned, is on the decline. This is due to the fact that much paving is now being made by the local authorities out of the ground clinker from refuse destructors, which makes a serviceable paving, though its durability is much questioned. Stuart's Granolithic is used for facings for all kinds of ornamental stonework and for moulded work.

The moulds used in the process are, as a rule, made from the best pine with a patent collapsible screw fitting for removing the moulds; the moulds are lined with plaster of Paris, and sometimes with zinc. A special mould is used in the manufacture of cover stones, a large quantity having been made for the General Post Office; this mould is made of cast-iron and washed over with linseed oil. The moulded work is said to be sufficiently set for removal from the moulds after 24 hours; it is then stacked in the open air to season, from one month to eight weeks.

The hardening process differs considerably from that employed in other stones, for in the case of Stuart's Granolithic, the hardness is obtained by the use of a shaking table, which consolidates the whole mass. But when hardness is required at short notice it is obtained by means of silicate of soda, which simply hardens the outer surfaces and so protects the inner material, the latter is said to harden in course of time, and the hardened outer skin prevents risk of injury through the use of the stone before being thoroughly seasoned.

In the case of floors the silicate is used when a particularly hard surface is required, but it is not applied until after the floor is laid. In short, the silicate, which is prepared from dissolved Farnham flint, is, in our opinion, simply a temporary hardening proceeding to avoid injury through premature use of the material.

This stone can be made in various colours, grey being the nearest approach to Portland, in which latter case Portland stone chippings are used in order to give it a natural appearance. The colours which are generally employed are claret, buff, yellow, and white, to match yellow and white Mansfield. These colours are obtained by the use of oxides.

Kirkcaldy found that the compressive strength of this stone was 552·4 tons per sq. ft. Its specific weight is 145 lbs. per cubit ft. It can be made with a concrete or concrete and cement face, and can be faced with granite chippings. It is largely used for staircases, and the cost is approximately for ornamental work 4s. per ft. cube, and for plain work 3s. 9d., which includes delivery, but not fixing, the price for the latter is from 9d. to 1s. per ft.

We do not think an artificial stone can be obtained that will match the Whitbed Portland in colour, but Stuart's Granolithic is, in our opinion, one of the best substitutes, though in the course of time no artificial stone can keep the white colour of Whitbed Portland, and their nearest approach is a dirty grey.

11. Chance's Artificial Stone. This stone is made by melting a basaltic rock known as Rowley Rag and found in Staffordshire. When melted it can be cast in moulds to the desired shape and is used for architectural decoration. Greenstone is sometimes used as a substitute for Rowley Rag, and it can be treated in exactly the same way. The moulds are usually of iron, which are lined with sand and then heated to a dull red heat, the Rag or Greenstone is then poured in and allowed to cool slowly. This is an important point for the reason that if the stone is cooled quickly the result will be a brittle and glassy mass.

12. Sorel Stone. This stone, which is not so widely known in this country as those which we have already mentioned, takes its name from its inventor, a French chemist, and is manufactured as follows:—Carbonate of magnesia is calcined and then mixed with finely-crushed marble or sand; it is then moistened with a liquid containing a large proportion of magnesium chloride, is pugged and then compressed into moulds made from almost any material, such as plaster, wood, etc., the former being more generally used. It takes about four days to set sufficiently to enable one to handle it, but can, if necessary, be removed with care from the moulds after about 24 hours. The inert material bound together should contain a proportion of from 3 per cent. to 15 per cent. of magnesia.

With regard to its strength when properly set and seasoned it should be capable of withstanding a compression of 5,000 to 21,560 lbs. per sq. in. This is the result of many experiments on 2-in. cubes of the material.

13. Patent Impervious Stone. This stone is manufactured by the Patent Impervious Stone Co., of Hammersmith, and is composed entirely of washed Red Leicestershire granite and heavy Midland Portland cement made specially for the company's use. After the stone is cast it is removed to the silicating tanks where it is allowed to remain for two or three weeks to undergo the process of hardening, which the manufacturers consider is absolutely essential in the manufacture of a good artificial stone.

This stone, therefore, belongs to the class of cement-concrete stones hardened by the use of alkaline silicate.

Various tints can be obtained, but that styled by the company "Brown Portland" appears to be most in vogue, and bears a close resemblance in appearance to the natural stone after which it is named.

14. Atlas Stone is made by the Atlas Stone Company, of Cambridge, from Leicestershire granite and a local brand of Portland cement, of medium rapidity of setting. This stone for architectural dressings can be made in a variety of tints, the permanency of which is guaranteed. Hardening is preferably carried out by immersion in water, followed by drying in an artificially-induced current of air at a slow velocity, although indurating by silicating solutions can be employed.

Paving slabs are prepared under a pressure of 400 tons on each slab, the sizes of which range from 4 to 6 ft. super.

The cost of the artificial stone for dressing averages 4s. 6d. per ft. cube for moulded work.

15. Impermeable Stone, manufactured by F. Bradford & Co., is composed of granite from various localities and cement obtained from the Associated Portland Cement Manufacturers, usually in the proportions of 2½ parts of granite to one part of cement. Hardening is done by exposing to air so that from three weeks to a month is required from date of order to that of delivery. For architectural dressings the price ranges from 3s. 6d. to 5s. per ft. cube, and that of paving from 2s. 9d. for 1 in. up to 4s. for 3 in.

16. Lascelles' Concrete is one of the oldest artificial stones still on the market and is now produced by W. H. Lascelles & Co., Ltd. In the early days of this material—some 30 years ago—the colour, particularly of red concrete, was apt to fade in an irregular and unpleasant manner, but great improvements have been achieved by experience in working. The concrete is usually, and where hard wear is required, made of granite chippings and cement of slow-setting quality, though Bath stone is also used for dressings and Derbyshire spar for steps. One especial feature of this stone is the sharpness of detail in moulded work which is obtained by the careful selection of suitable materials for moulds. Hardening in air is adopted, the time for delivery from date of order is three weeks and the average price for dressings is 3s. per ft. cube.

17. Bennett's Improved Granitic Stone, by Messrs. James Bennett & Co., is chiefly used for pavings, staircases and steps, and is prepared from Scotch granite and specially-made Portland cement from the Medway. When turned out of the moulds the steps, etc., are allowed to harden by exposure to the air for a month under cover, though silicating is sometimes adopted for work that has to be hurried.

18. Christie's Patent "Stoneface" Stone has principally been employed in the North of England, the original works of the Christie Patent Stone Co., Ltd., who are the makers, being at Hull. This stone is used exclusively for architectural dressings as distinct from paving, and is made in yellow, red and Portland stone colours. The crushing strength by Kirkcaldy's tests is about 300 tons per sq. ft. Delivery is made in five or six weeks after receipt of order, and the cost averages 3s. per ft. cube.

19. Hodkin & Jones, Ltd., of Sheffield, make artificial stone for dressings of hard limestone with sand and Portland cement, the latter specially manufactured for the purpose. The usual colour of this stone is a warm buff, but any tint can be matched. Plain material can be delivered in about 14 days and moulded work in two or three weeks, and the price averages 3s. 6d. to 4s. per cube ft. For staircases, etc., a wear-resisting material is made by the employment of Leicestershire granite instead of limestone.

20. "Imperishable" (Castle Brand) Architectural Concrete Masonry is made by Daniels & Co., of Lincoln, from local stone and Portland cement in the proportions of three parts of stone to one of cement. It is made in almost all the colours of ordinary building stones, except light cream, such as Bath; and is hardened by drying in air naturally.

21. ***Malcolm Macleod & Co.*** make a "granitic" stone of crushed Leicestershire or Guernsey granite and Portland cement, cast in carefully-prepared moulds, the faces being finished off whilst the stone is yet green, but without the addition of any facing. The stones are tanked in a solution of silicate of soda for induration. For dressings crushed Portland stone and cement are used and slightly coloured. The approximate cost for dressings is 4s. per ft. cube.

22. ***A. J. Phillips & Co.*** use in the manufacture of their artificial stone for stairs, floors, pavings and architectural dressings, Leicestershire and other granites, as well as York stone and Portland stone, combining these with Portland cement obtained from Messrs. J. B. White & Bros., and the cost of their stone for dressings is about 5s. to 6s. per ft. cube.

23. ***B. Ward & Co.*** follow somewhat similar lines, using Guernsey and Leicestershire granites and also, if desired, hard limestone from Buxton with best quality Portland cement, taking special care to use this sufficiently cooled. The price for architectural dressings averages 5s. 6d. or 6s. a ft. cube.

24. ***John Ellis & Sons, Ltd.,*** of Leicester, prepare their artificial stone from washed Mountsorrel granite and heavy Portland cement of their own manufacture, which has a tensile strength of 600 to 700 lbs. to the sq. in. of a briquette seven days old. The proportions of the materials are three parts of granite to one part of cement. The usual colours are in imitation of Portland, Bath and local stones, though many others can be obtained and the hardening of the stone is preferably effected by from four to six weeks' exposure to air, though silicating is sometimes employed. The price of the stone for dressings is approximately from 3s. 3d. to 3s. 9d. per cubic ft.

25. ***Gibbs Brothers,*** of Loughborough, whose concrete works are at Mountsorrel, also use that granite with Portland cement for their artificial stone, which is immersed in water to harden. The price for dressings is about 3s. 6d per ft. cube.

MEMORANDA.

***Memoranda** and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.*

Waterproofing Concrete.—Not far removed from the question of water-proofing concrete are the interesting particulars put forward by Mr. M. R. Barnett before the Institution of Civil Engineers in respect to the repair of a limestone concrete aqueduct, with a view to overcoming leakage troubles. The Thirlmere Aqueduct, which is 96 miles long, and conveys water from Thirlmere to Manchester was found to be leaking in a certain portion measuring about three miles, and Mr. Barnett was called in to investigate the matter after several attempts to stop the leakage had failed. He found upon testing that there was a loss of over 1¼ million gallons of water in 24 hours, and indicated where the leakage was, and its extent. Examining the concrete it was observed that the leakage was caused by the action of the soft water on the limestone in the concrete. Holes were discovered in the culvert floor, and each small piece of individual limestone was seen to be much water-worn. To find out the rate of action of the water upon the limestone experiments were made, and the Portland cement and mortar (1 of cement to 1 of sand) used for the repairs were similarly tested. Chemical analyses were made of the limestone, the Portland cement, and the sand, the results of both tests and analyses being given. After three months' immersion the rate of wastage of the blocks varied from 6·83 per cent. per annum to 18·10 per cent. per annum, and after six months' immersion from 6·75 per cent. per annunm to 17·09 per cent. per annum. The sample blocks of Portland cement and mortar, instead of losing, actually gained slightly in weight—namely, the cement block 5·47 per cent. per annum and the mortar block 3·47 per cent. per annum. It was decided that the whole water surface of the concrete in which limestone had been used should be refaced by Portland cement mortar, not less than one inch thick.

* * *

Correction.—We desire to correct an error which appeared in our previous issue, when we stated that Messrs. "D. J. Sullivan & Co." had informed us they were carrying out works at Southampton with the Kahn Bars. The name of this firm should have been Messrs. D. G. Somerville & Co., of 72, Victoria Street, London, S.W. The work referred to is the reconstruction of the Town Quay in reinforced concrete. We tender our apologies to Messrs. Somerville for the mistake.

* * *

Trade Announcement.—We are informed by the General Agent for the Coignet System of Armoured Concrete Construction, that they have obtained through their Licencees, Messrs. Peacock Bros., of Brixton, the contract for the floors, posts, and roofing for a new warehouse for Messrs. J. Grossmith Sons and Co., to be built at the corner of Duke's Head Passage and Ivy Lane, Newgate Street, E.C.

* * *

Distinctions. — At a general meeting of the North-East Coast Institution of Engineers and Shipbuilders, the President presented to Mr. J. Mitchell Moncrieff the Institution's gold medal for his paper last year on "Commercial Dry Docks."

The Norman Medal of the American Society of Engineers has been awarded to our valued contributor, Captain John Sewell, of Washington, D.C., for his paper, "The Economical Design of Reinforced-Concrete Floor Systems for Fire-Resisting Structures."

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

THE NEW REINFORCED-CONCRETE COALING JETTY AND VIADUCT AT PORT TALBOT.

THE coal tip recently erected in the new dock of the Port Talbot Railway and Docks Company was specially designed for the rapid bunkering of the largest cargo and other steamers using the Bristol Channel. The tip is one of the highest and most powerful appliances of the kind hitherto built in this country, and the jetty is noteworthy as the first reinforced concrete structure of the kind and for the same purpose in the world.

The jetty was built to the designs and under the superintendence of Mr. W. Cleaver, the chief engineer to the Port Talbot Railway and Docks Company, in accordance with the Hennebique system, and we may mention the fact that the reasons which influenced the adoption of reinforced concrete were the increased life and stability of the material as compared with timber or steel, and the savings anticipated in respect of maintenance charges, for reinforced concrete requires neither the reairs nor the painting which constitute so heavy a tax upon the owners of structures built of the materials hitherto employed.

The jetty is founded upon twenty-eight piles driven to a depth of about 12 ft. below dock bottom, and from 46 to 47 ft. below quay level. Most of these piles measure 14 ins. sq., but in some places the dimensions of 16 ins. sq. were adopted. A reinforced concrete cylinder of 36 ins. diameter was sunk around each pile in the front row, thus adding considerably to the strength of the construction.

For the protection of vessels coming alongside, the entire front of the jetty is fitted with horizontal and vertical timber fendering.

As is now well known any well made reinforced concrete pile can be driven through any strata capable of being penetrated by any other description of pile. The only special treatment is the application of a suitable cap filled with sand to distribute the forces of the blow and thus to avoid any damage to the head of the pile. The pile is then driven by blows from a monkey in the usual manner.

The heads of the piles at Port Talbot are connected by reinforced concrete main and secondary beams, which are covered by a 5-in. decking slab of the same material, the three elements of the construction being strongly reinforced by longitudinal bars and vertical stirrups, the latter being for the purpose of resisting shearing stresses, the reinforcement of the deck slab including transverse as well as longitudinal bars, and it should be added that all parts of the jetty are continuous and monolithic.

For the support of the gantry, the platform of which is 20 ft. above quay level, some of the piles are prolonged to form columns which are rigidly braced by intersecting diagonals as represented in *Figs.* 1 and 2. The heads of the columns are connected, in the manner already described, by main and secondary beams and a continuous decking slab.

The approach viaduct consists of longitudinal and transverse beams and deck slab, forming a girder bridge of ample strength and elasticity for heavy railway traffic. The outer end of the viaduct is connected with a plain concrete abutment into which the reinforcing bars are securely anchored, and which acts as a retaining wall to resist the pressure of the embankment bringing the approach railway up to the coal tip. *Fig.* 2 gives a good idea of the gantry supports and approach viaduct.

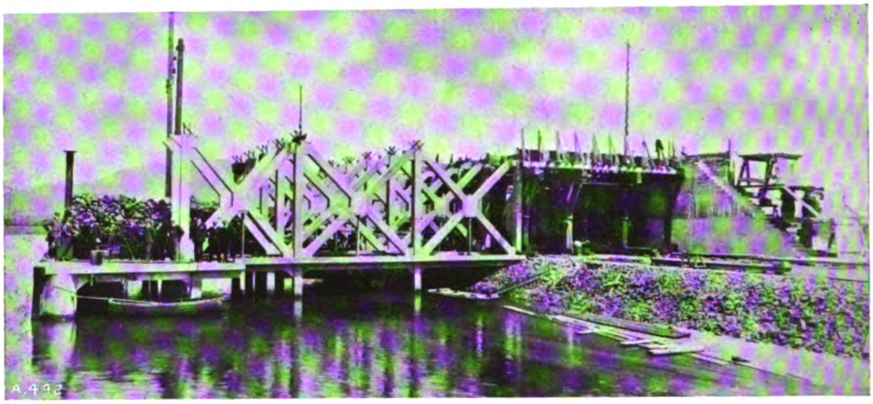


FIG. 1. REINFORCED CONCRETE COALING JETTY AT PORT TALBOT.

The deck slab of the jetty at quay level is covered by 4 ins. of macadam, and cinder ballast to the depth of 30 ins. is laid on the gantry and viaduct as a foundation for the permanent way. Bollards are built into the jetty to facilitate the handling of vessels.

Before the coal tip was erected the supporting area was tested by the application of a load consisting of 320 tons of steel rails, slag, and other materials, this being 50 per cent. above the normal working load. The satisfactory nature of the test may be judged by the following figures taken from a report by the engineer.

Levels were taken before the jetty was loaded, another set while it was fully loaded, and a third set after the load had been removed. In the subjoined tables we give the chief results :—

TABLE I. SETTLEMENT OF JETTY WHILE FULLY LOADED.

No.		Levels Before Test.	Levels During Test.	Temporary Settlement.	
				Decimals of an inch.	Fractions of an inch.
1	....	9·815	9·775	0·48	$\frac{1}{2}$ in. bare
2	....	10·140	10·110	0·36	$\frac{3}{8}$,, ,,
3	....	10·175	10·130	0·54	$\frac{1}{2}$,, full
4	....	9·795	9·770	0·30	$\frac{5}{16}$,, bare
5	....	9·765	9·715	0·60	$\frac{5}{8}$,, ,,

TABLE II. SETTLEMENT OF JETTY—LOAD REMOVED.

No.		Levels Before Test.	Levels After Load Removed.	Permanent Settlement.	
				Decimals of an inch.	Fractions of an inch.
1	....	9·915	9·79	0·30	$\frac{5}{16}$ in. bare
2	....	10·140	10·12	0·24	$\frac{1}{4}$,, ,,
3	....	10·175	10·14	0·42	$\frac{3}{8}$,, full
4	....	9·795	9·78	0·18	$\frac{3}{16}$,, bare
5	....	9·765	9·74	0·30	$\frac{5}{16}$,, ,,

From Table II. it will be seen that the maximum permanent settlement was only about $\frac{3}{8}$ in., which is very small for a work of this character. Other measurements showed the maximum deflection of the longest beam, with the clear span of 14 ft. 3 ins., in front of the jetty, to be only one-eighth of an inch, or $\frac{1}{1368}$th of the span.

These results demonstrate in a striking manner the strength and remarkable stiffness of reinforced-concrete jetty construction when properly designed and executed.

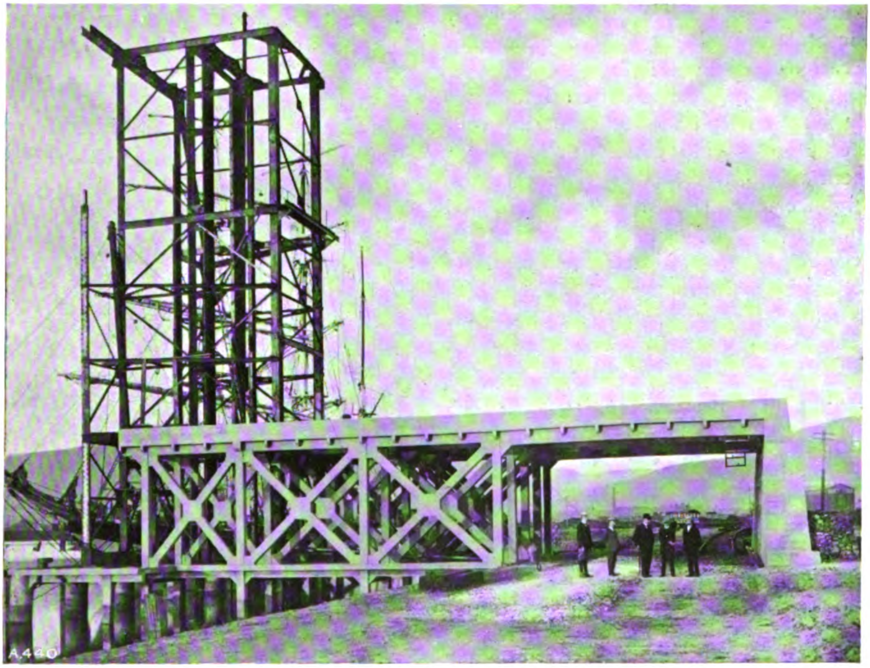


FIG. 2. REINFORCED CONCRETE COALING JETTY AT PORT TALBOT.

To provide independent support for two weighbridges and a turntable on the approach railway, timber trestles were built up from normal ground level and afterwards covered by the railway embankment.

In view of the fact that the advantages of reinforced concrete, in respect of strength and durability, were fully appreciated as special recommendations for the employment of that material in the construction of the new jetty, some of our readers may possibly ask why it was not also applied to these foundations, where its resistance to the destructive influences, always certain to affect the best of timber, would have been an absolute safeguard against the effects of decay, to say nothing of its superior rigidity and elastic strength.

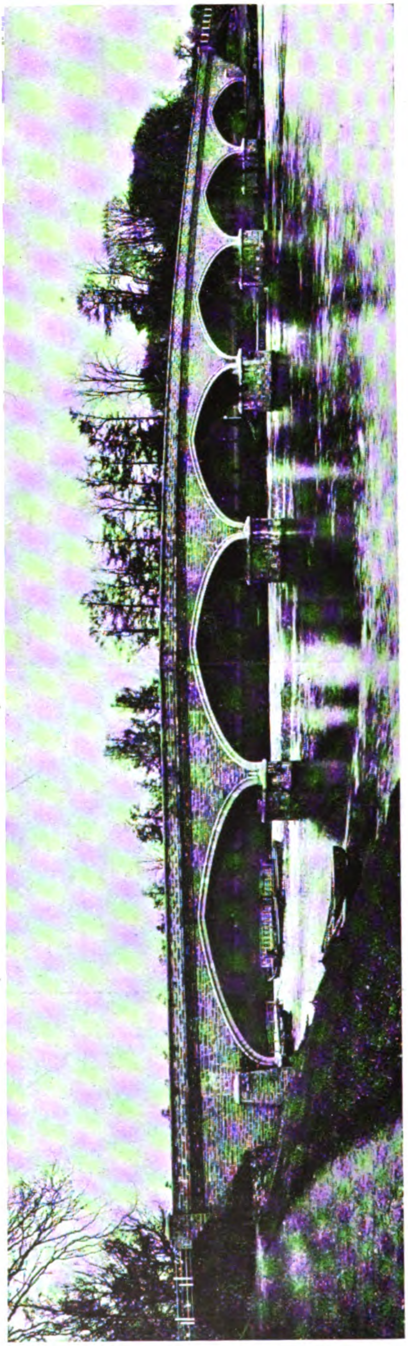
The answer to any such question is that the engineer had on hand a considerable quantity of sound timber, taken from an uncompleted jetty which had to be removed to make room for a new wharf, and as this material had to be utilised it was applied to the construction of the foundations of the trestles in question. All the timbers were well coated with "carbolineum" as a preservative against decay, although this is a fairly remote contingency in view of the fact that the embankment is composed almost entirely of clean sand. Moreover, before any serious decay can develop, the embankment will be so far consolidated as to be capable of supporting the comparatively light loads due to the weighing machines and turntable, especially as these loads are well distributed over concrete beds of large area. Thus it will be seen that the employment of timber for the purpose mentioned is thoroughly justified by structural as well as by economic considerations.

In concluding this brief description, we may mention that the whole of the concrete used was made with Portland cement of approved quality, the aggregate being fresh water, sand, and crushed granite, mixed in the proportions of 1 part of cement to 4 parts of aggregate. Mild steel made by the Siemens-Martin process was employed exclusively for the purposes of reinforcement. The contractors for the jetty and viaduct were Messrs. Topham, Jones & Railton, of Westminster.

A CONCRETE BRIDGE IN SCOTLAND.

Kinclaven Bridge, over the River Tay, 10 miles above Perth, affords a good example in the use of concrete, of adapting the materials ready at hand for the purpose of obtaining an economical form of construction, and at the same time presenting a pleasing structure in harmony with the surroundings.

The bridge is built entirely of concrete, faced, with the exception of the arch rings and impost courses, with red sandstone from a local quarry, so that the structure, while being in essence of concrete, has all the appearance of the native stone.


Kinclaven Bridge over the Tay, Perthshire.

The arches, which are six in number, and 61 ft. 6 in. span, with a rise of 13 ft. 6 in. above springing, are in the form of two ellipses intersecting obliquely at the crown so as to give a slightly Gothic profile, and with a vertical rise of 1 ft. above the impost courses. The arch ring is of 3 to 1 concrete, tapered from 2 ft. thick at the springing to 18 in. at the crown, the exposed faces being of moulded voussoirs, upon the upper part of which is worked a heavy semi-circular projection. The ring is reinforced by a haunching of 8 to 1 concrete, and clamped at the crown with short lengths of bent service rails.

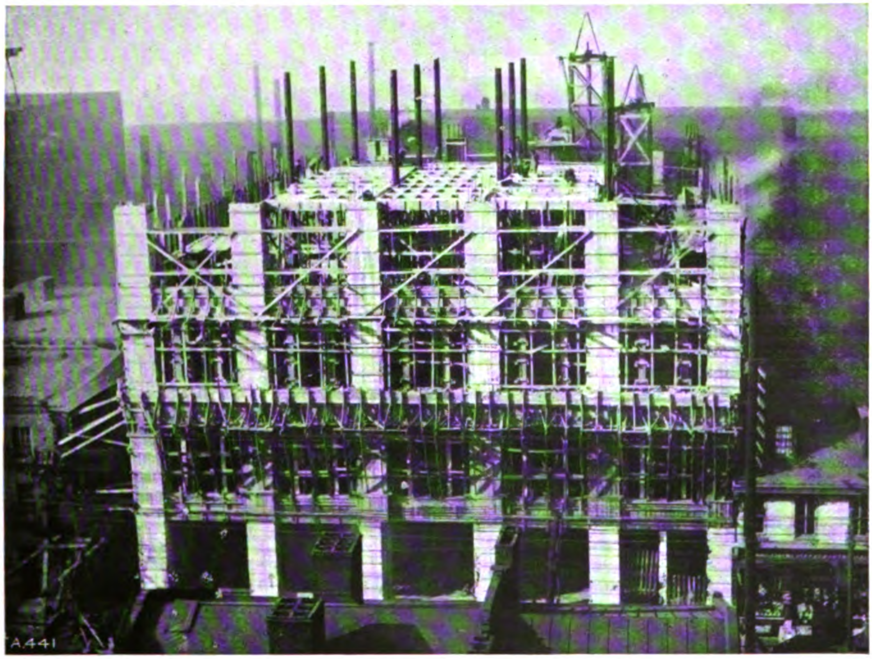
The impost courses are of moulded concrete blocks, 12 in. deep, with a semicircular projection. The piers, which are pointed to form cut-waters, are 5 ft. 6 in. thick at the top and slightly battered. The foundations, which are in compact gravel, are of 5 to 1 concrete enclosed in a close sheeting of American elm 9 in. thick, which was driven to a depth of 10 ft. below the river bed.

The bridge, of which we present an illustration, cost only just over £6,000, a fact which is largely due to advantage being taken of the abundance of raw material close at hand, the gravel of the river bed at the site being used for the concrete, while the stone was brought from a quarry some two miles distant. It was thus only necessary to import the cement and the timber sheeting for the foundations.

The bridge was designed and carried out under the supervision of Messrs. Formans & McCall, Glasgow, the contractors being Messrs. James Young, Ltd., Glasgow.

REINFORCED CONCRETE OFFICE BUILDING IN PITTSBURG, U.S.A.

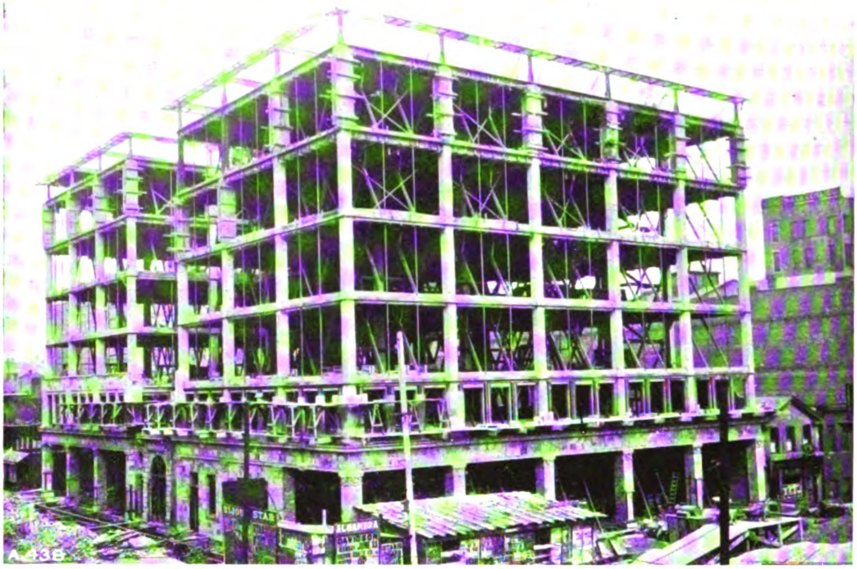
This building, of which we present a photograph taken during course of construction, is to be composed of 10 storeys and a basement, 80 ft. by 100 ft. In addition to this, a reinforced concrete chimney, 48 in. in diameter, and 160 ft. high, will be supported independently of the building.



Reinforced Concrete Office Building in Pittsburg, U.S.A.

The floors have been designed for exceptionally heavy loads, the second, third and fourth floors being designed for 300 lb. per sq. ft., and the floors above for 250 lb. per sq. ft.—which is over three times the usual floor load for office buildings.

It is to be used as an office, manufacturing and storage building by the Bernard Gloekler Co., and Messrs. Ballinger & Perrot, 1,200 Chestnut Street, Philadelphia, are the architects.

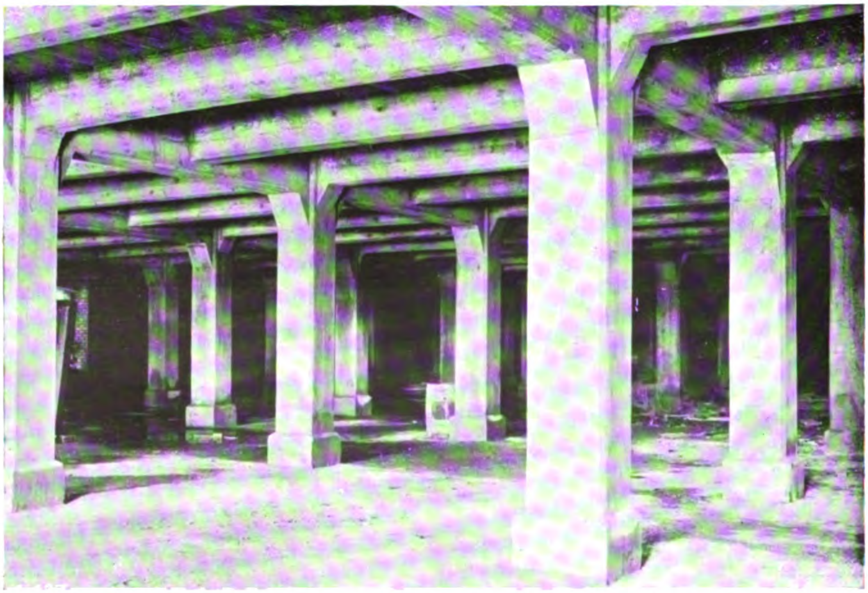


SKELETON CONSTRUCTION WORK OF THE UIHLEIN BUILDING, MILWAUKEE.

TWO AMERICAN EXAMPLES.

The photograph of the Uihlein Building at Milwaukee, which has been built with "Kahn" bars, shows the entire construction of the skeleton type of reinforced concrete work. The walls are supported by the concrete framework.

Of the reinforced concrete warehouse built for Messrs. Farwell & Co., at St. Paul, we present an interior view. The building is nine storeys high, and the floors throughout are designed to carry a load of 5 cwt. per ft. super. All the columns, girders and beams of this building were constructed in reinforced concrete with "Kahn" bars.



REINFORCED CONCRETE WAREHOUSE, ST. PAUL, MINNESOTA.

NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

REINFORCED CONCRETE RAILWAY SLEEPERS IN ITALY.

IN the number of this journal for March, 1906, some account was given of the types of reinforced concrete railway sleepers in use in America. We are now enabled to give particulars of sleepers in use on Italian railways.

A form of tie designed by Sr. Ausano Caio was introduced experimentally on the Southern Italian Railways in 1900, and is shown in *Fig.* 1. The weight of each sleeper was 130 kg. Bending tests gave the results shown graphically in *Fig.* 2, the deflections being given in millimetres. Practical trials were made on the railway with such success that 300,000 of such ties have now been ordered. It is intended to lay them at first in and near the stations, where the speed of the trains is reduced, and, in the event of favourable results being obtained, to extend their use to other parts of the line.

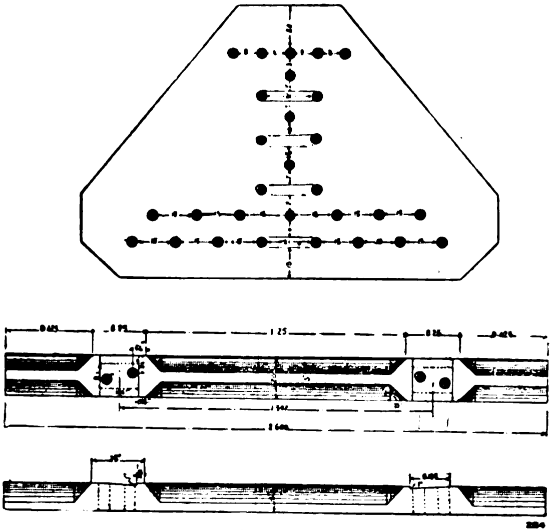


FIG. 1.

Several modifications have been made in the original design, and the form now adopted is shown in plan in *Fig.* 3 and in elevation in *Fig.* 4. The reinforcement consists of round iron rods, arranged in four layers, as shown in *Fig.* 5, and bound together by means of iron wire. Pieces of iron gauze are inserted in the middle of the ties and under the chairs. Vertical rods, bound up with the remainder of the reinforcement, are introduced underneath the chairs. The pyramidal wooden plugs (*Fig.* 6) have now been replaced by conical plugs (*Fig.* 7). Sections of the ties at the centre and below the chairs are shown in *Figs.* 8 and 9 respectively. The specification of the materials to be used in the construction of these sleepers is a rigid one, and tests are required in all cases. The dimensions of the different parts are indicated on the figures.

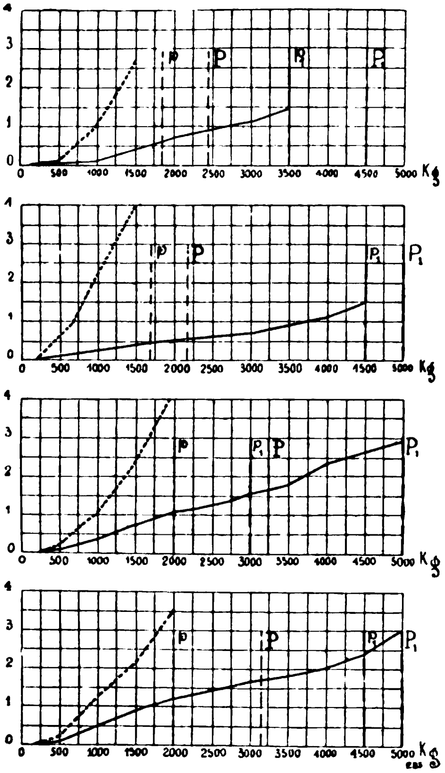


FIG. 2.

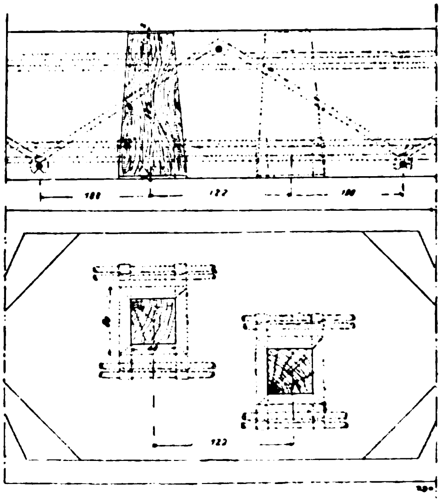


FIG. 6.

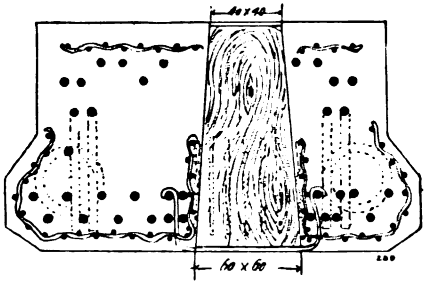
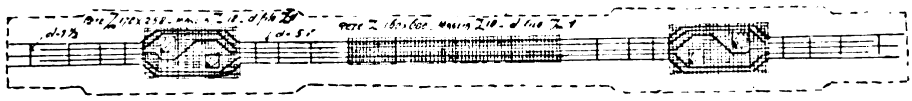
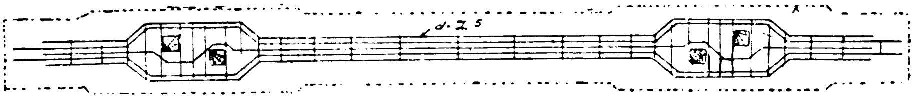


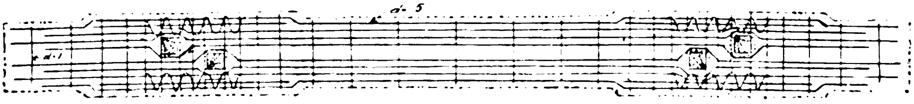
FIG. 7.



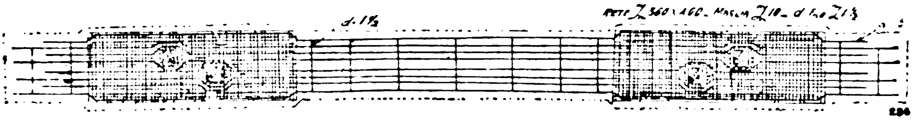
1st layer.



2nd layer.



3r l layer



4th layer

FIG. 5.

REINFORCED CONCRETE SHINGLES FOR ROOFING.

THE purposes to which reinforced concrete is now applied are constantly increasing, one of the latest being its application as a covering for roofs—not in the form of a continuous slab or sheet—but as shingles to be used in place of slates or tiles. According to the *Engineering News*, machines are now being constructed by Messrs. Wickes Bros., Saginaw, Michigan, for the manufacture of such shingles, the machines making not only the plain tiles, but also those for hips and ridges.

Reinforcement is adopted in order to prevent the shingle falling to pieces if it should become cracked. Steel or copper wires are used for reinforcement, and are set in place lengthwise and transversely, the loops and eyes for nailing being of the same material, and fitting in recesses in the mould.

The machine has a table at each end, the entire length being about 45 ft. The size of the plain shingles is 16 in. long by 8 in. wide, by ½ in. thick at the butt; the shingle tapers slightly in thickness towards the top. Various sizes and shapes can be made in a variety of colours. The concrete used is composed of 1 part Portland cement to 2½ parts clean, sharp sand. The shingles are not fastened rigidly to the roof, but are connected somewhat loosely to allow for expansion and contraction. These shingles are said to be guaranteed by the makers for twenty-five years.

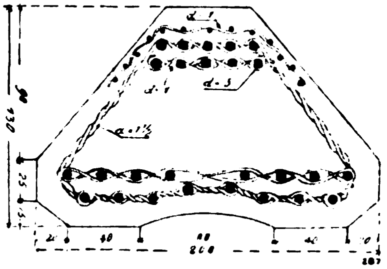


FIG. 8.

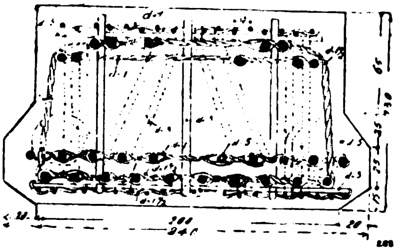


FIG. 9.

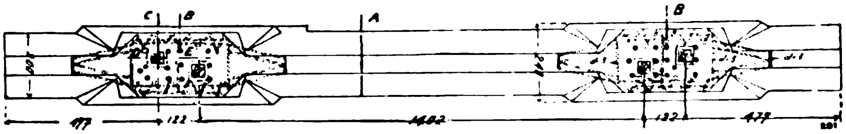


FIG. 3.

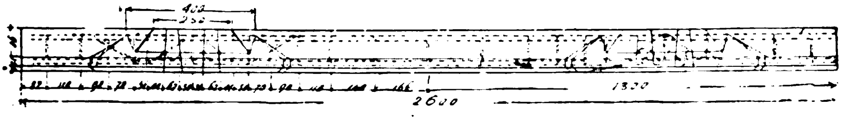


FIG 4.

TESTS WITH CONCRETE

AT HOME AND ABROAD.

We consider that the absence of reliable information as to the various tests carried out with concrete both at home and abroad has frequently led to misconceptions as to the qualities of this material, and we shall thus for the present accord considerable space to the presentation of authentic data that may be of service to those employing concrete in its various forms. The tests which will particularly call for our attention are those relating to strength, fire-resistance, and waterproofing.—ED.

TESTS ON CONCRETE AND REINFORCED CONCRETE COLUMNS AT THE WATERTOWN ARSENAL.

SUMMARISED AND ANNOTATED BY
CHARLES F. MARSH, M.INST.C.E.

IN a paper read before the American Society for Testing Materials, Mr. James E. Howard describes the results of tests on columns of practical dimensions of plain concrete and concrete with longitudinal and hooped and longitudinal reinforcements, and we reproduce the author's conclusions here, in the hope that they will be of interest to our readers.

The general dimensions of the columns were from 10 to 12 in. in diameter, and 8 ft. in length. They were made in vertical moulds and of wet mixtures, hardened in air, and were tested in a horizontal position. The columns were constructed with iron plates at the top and bottom to give an even bearing, an initial pressure being applied by side rods and turnbuckles, to permit of their being handled while placing in the testing machine. The load was increased by increments of 50 lb. per square inch, the deformation being measured for each addition, and the column allowed to return to the initial loading for the measurements of the sets. The gauge length was 50 in. equidistant from each end of the columns. Mr. Howard states that the series of tests was by no means completed, and there had been little opportunity for comparisons and deductions to be made. He refers, however, to several features of interest, and has prepared a number of diagrams illustrating these, which we also present.

Diagram No. 1 illustrates the compressive strengths of mortar columns, plain and reinforced with longitudinal ¾ in. Ransome bars, and shows the progressive loss of strength as the mortar becomes leaner. The ultimate strength of the 1 : 1 mortar column was beyond the range of the testing machine.

Each of the mixtures except the 1 : 1 were reinforced with 8 bars, and the 1 : 5 mixture was also tested with a reinforcement consisting of 13 bars, the respective percentage of reinforcement being 2·86 and 4·63.

The black portion at the bottom of the diagram shows the relative amounts of reinforcement.

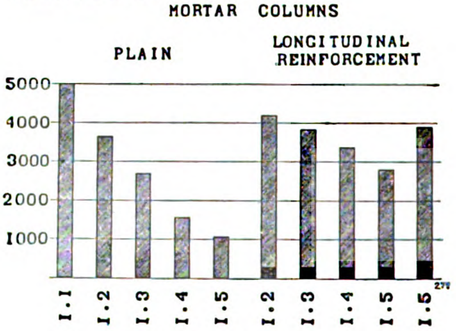


Diagram No. 1.

The bars extended from end to end of the columns, and bore directly against the compression platforms of the testing machine. No lateral reinforcement was employed in these columns.

Diagram No. 2 represents the strength of rich and lean mortars, plain and reinforced with hoops and longitudinal angle bars in a similar manner to that adopted in the Cummings system. The hoops measured 1·5 by 0·12 in. and were lapped and riveted. The results of the tests are clearly shown in the diagram. The addition of two parts of trap rock to the 1 : 1 mortar for the hooped columns reduced the strength from 5,980 to 5,433 lb. Mr. Howard states that the loss in strength, by the addition of stone to the mortar, has occurred in a number of cases, and is not peculiar to this example.

The weaker mortar, when hooped, increased in strength from 2,766 to 3,002 lb. with an addition of 8 parts of trap rock. The hoops were spaced 2½ in. apart in the clear, this spacing allowing the lean mortar to flake off, while the concrete remained in place, due to the larger size of the broken stone.

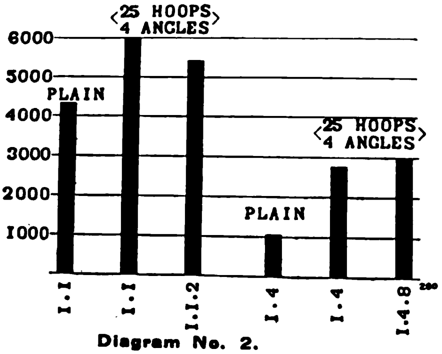


Diagram No. 2.

Diagram No. 3 gives the results obtained on columns of the same mixture of 1 : 2 : 4 concrete, plain, reinforced with hoops only and with hoops and longitudinal angle bars as shown. The strengths of the various columns is given in Table I. :—

TABLE I.

Description of Column.	Strength lbs. per sq. in.
Plain concrete	1,413
13 hoops	2,332
13 hoops and 4 angles	3,029
25 hoops	3,428
25 hoops and 4 angles	4,189
47 hoops	5,289

The results demonstrate that the hoops and longitudinal both contribute towards increasing the ultimate resistance. Mr. Howard states that although the ultimate strength is increased by hooping to the extent shown in Table I., the rigidity of shape does not advance in a corresponding degree, and that this is an important feature to be considered when judging of the advantages of exterior lateral support as compared with longitudinal reinforcement, or the gain in both strength and rigidity which accompanies the employment of rich cement mixtures. He points out that whereas any desired strength may be obtained by lateral reinforcement, if sufficient metal is used, it is obvious that a certain amount of longitudinal deformation must be necessary before the hooping reinforcement becomes effective, which, in the case of lean mixtures, involves a considerable direct deformation of the column.

Diagram No. 4 represents several strong columns, the strength being obtained either by the composition of the mortar or by the reinforcement employed. Table II. gives the columns in the order of their respective resistances.

TABLE II.

Description of Column.	Strength lb. per sq. in.	Relative rigidity.
1 to 1 mortar	5,011	2
1 to 2 mortar 8 ¾ in. Ransome bars	4,200	3
1 to 2 to 4 concrete, 25 hoops and 4 longitudinal angles	4,180	5
1 to 5 mortar, 13 ¾ in. Ransome bars	3,905	4
1 to 1 to 2 concrete	3,900	1
1 to 3 to 6 concrete, 25 hoops and 4 longitudinal angles	3,862	6
1 to 4 to 8 concrete, 25 hoops and 4 longitudinal angles	3,002	7

Diagram No. 5 shows the relative rigidity of these columns. The order of the relative rigidities is given by the number in the right hand column of Table II.

It will be seen that the plain concrete columns have the greatest and the hooped columns the least rigidity, which Mr. Howard points out as being an important feature of the tests.

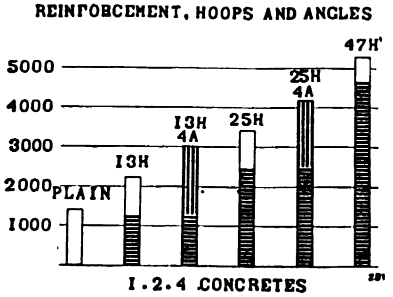


Diagram No. 3.

It was even found that plain columns were slightly more rigid, over the range of stresses plotted, than the same mixtures in which longitudinal bars were used as a reinforcement. This occurred in so many cases that Mr. Howard sought for some explanation why the presence of steel bars, themselves so much more rigid than the concrete, should not increase the rigidity of the column as a whole. He considers that it is not improbable that the longitudinal deformation of the column is so far restricted by the steel bars that minute cracks are developed during the early stages of hardening of the concrete, and states that internal strains, without the presence of cracks, would hardly account for this behaviour. The difference between plain and longitudinally reinforced columns is not very great in this respect, being considerably more marked when hooping is employed.

Mr. Howard is conducting a series of experiments for comparison of plain and hooped columns of different mixtures, and expects to find that the leanest mixtures will show the greatest relative compressibility. He holds that while lateral reinforcement is effective in raising the ultimate strength for loads once applied, it does not impart rigidity to a weak concrete, and suggests a doubt as to the value of hooping reinforcements, as a method of raising the limit of endurance, against continued and repeated stresses.

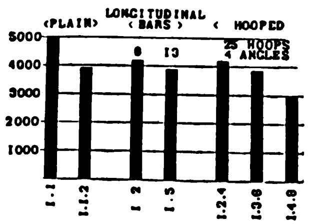


Diagram No. 4.

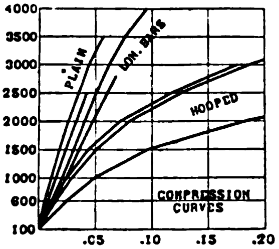


Diagram No. 5.

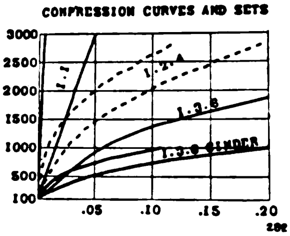


Diagram No. 6.

Diagram No. 6 shows the range in compressibility and the sets developed, in different mixtures, all except the 1 : 1 mixtures being reinforced with hoops. The details of reinforcement are given in Table III.

Diagram No. 7 gives the moduli of elasticity of the above columns, referring to values over a range of 500 lb. per square inch next above the initial load. The columns were loaded with successive higher stresses and then returned to the range from 100 to 600 lb., at which time the micrometer observations were made.

The values obtained for the moduli of elasticity are given in Table III.

TABLE III.

	lb. per sq. in.
1 : 1 MORTAR, PLAIN.	
Original value of E	3,378,000
After a load of 1,000 lb.	3,247,000
,, 1,500 lb.	3,247,000
,, 2,000 lb.	3,205,000
,, 2,500 lb.	3,165,000
,, 3,000 lb.	3,086,000
,, 3,500 lb.	3,086,000
1 : 2 : 4 CONCRETE, 25 HOOPS.	lb. per sq. in.
Original value of E	2,874,000
After a load of 1,000 lb.	2,551,000
,, 1,500 lb.	2,016,000
,, 2,000 lb.	1,532,000
,, 2,500 lb.	1,337,000
,, 2,800 lb.	1,244,000
1 : 3 : 6 CONCRETE, 48 LIGHT HOOPS, 4 ANGLE BARS.	lb. per sq. in.
Original value of E	1,220,000
After a load of 1,000 lb.	899,000
,, 1,500 lb.	801,000
,, 2,000 lb.	912,000
1 : 3 : 6 CONCRETE, CINDER, 25 HOOPS.	lb. per sq. in.
Original value of E	702,000
After a load of 850 lb.	538,000
,, 1,000 lb.	426,000

Rich mortars do not show any considerable loss in the value of the modulus of elasticity, when examined over an early range of loads, succeeding the application of subsequent higher stresses, while the leaner reinforced mixtures are subject to decided changes.

For these later columns, after the application of each higher load there is a difference in the rate of compressibility under lower stresses, the modulus in some cases dropping to less than one-half its original value, from which it is evident that the proportion of the load carried by the steel in combination with the concrete is subject to great fluctuations. Mr. Howard is of the opinion that this feature deserves consideration in the case of reinforced beams, when they are studied in the manner in which these column tests were carried out. He points out that compressive stresses exceeding 50,000 lb. per square inch are of frequent occurrence in columns tested to their ultimate resistance, whence it follows that the steel employed for longitudinal reinforcement should have an elastic limit not less than the above.

This, however, only applied to test pieces since in actual practice the limits of working loads will be kept considerably below the ultimate.

Diagram No. 8 shows the stress-strain curves of four columns, indicating that the curves of ascending and descending stresses do not coincide. This departure increases with the application of successively higher loads.

The curves shown in Diagram No. 8 were obtained after the columns had been loaded to the amounts given in Table IV.

TABLE V.—CONCRETE AND MORTAR COLUMN TESTS AT WATERTOWN ARSENAL, COLUMNS 8 FT. HIGH.

Diameter of column in inches.	Composition.				Age.		Reinforcing Metal.	Gross sectional area.	Weight of concrete or mortar per cubic foot.	Compressive strength.	
	Cement.	Sand.	Stone or Cinder.	Kind of stone or cinder.	Months.	Days.		sq.in.	lb.	Total. lb.	Per sq.in. lb.
12.35	1	2	4	¾ to 1½-in. trap rock	5	8	2-in. mesh wire cage	119.79	149.6	263,538	2,200
12.25	1	2	4	" "	5	13	3-in. mesh wire cage	117.86	151.3	242,000	2,053
12.45	1	2	4	" "	5	13	" "	121.74	149.4	318,000	2,619
12.25	1	3	6	" "	5	8	2-in. mesh wire cage	117.86	150.1	159,111	1,350
12.45	1	3	6	" "	5	8	" "	121.74	145.7	168,000	1,380
12.40	1	3	6	" "	5	8	" "	120.76	143.1	183,500	1,520
12.34	1	3	6	" "	5	12	3-in. mesh wire cage	119.60	147.6	197,340	1,650
12.35	1	3	6	" "	5	11	" "	119.79	149.6	206,000	1,720
10.40	1	1	0	None	6	11	None	84.95	132.6	367,000	4,320
10.40	1	1	0	"	6	12	25 1.5-in. hoops and 4 angles	84.95	132.6	508,000	5,980
10.45	1	1	2	¾ to 1½-in. trap rock	5	0	" " "	85.77	149.1	466,000	5,433
10.38	1	4	0	None	6	8	None	84.62	118.7	88,851	1,050
10.40	1	4	0	"	6	8	25 1.5-in. hoops and 4 angles	84.95	119.9	235,000	2,766
10.40	1	4	8	¾ to 1½-in. trap rock	6	11	" " "	84.95	146.6	255,000	3,002
10.40	1	2	4	" "	5	16	None	84.95	150.0	120,000	1,413
10.38	1	2	4	" "	6	6	13 1.5-in. hoops	84.62	149.2	188,900	2,232
10.38	1	2	4	" "	6	5	25 1.5-in. hoops	84.62	148.6	290,100	3,428
10.35	1	2	4	" "	6	6	47 1.5-in. hoops	84.13	149.4	445,000	5,289
10.38	1	2	4	" "	6	7	13 1.5-in. hoops and 4 angles	84.62	150.7	256,300	3,029
10.40	1	2	4	" "	0	15	25 1.5-in. hoops and 4 angles	84.95	144.2	260,400	3,065
10.30	1	2	4	" "	5	12	" " "	83.32	150.7	349,000	4,189
12.00*	1	2	4	" "	5	12	" " "	113.10	149.4	370,000	3,271
10.36	1	2	4	½ to ¾-in. trap rock	5	12	48 1-in. hoops and 4 angles	84.30	147.2	324,000	3,843
11.95*	1	2	4	" "	6	0	" " "	112.16	148.2	335,200	2,989
10.38	1	3	6	¾ to 1½-in. trap rock	5	11	None	84.62	148.2	63,465	750
**10.38	1	3	6	" "	6	4	25 1.5-in. hoops	84.62	145.9	162,300	1,918
10.38	1	3	6	Cinders	6	4	" "	84.62	101.3	96,000	1,134
10.35	1	3	6	¾ to 1½-in. trap rock	5	11	25 1.5-in. hoops and 4 angles	84.13	148.3	325,000	3,863
12.02*	1	3	6	" "	5	3	" " "	113.47	144.6	299,000	2,634
10.36	1	3	6	½ to ¾-in. trap rock	5	11	48 1-in. hoops and 4 angles	84.30	138.9	212,000	2,515
11.95*	1	3	6	" "	5	13	" " "	112.16	142.2	259,000	2,309
12.00	1	2	4	¾-in trap rock	5	11	3 Kahn bars and 11 hoops	113.10	145.4	265,500	2,350
12.00	1	2	4	" "	5	8	" " "	113.10	145.6	237,510	2,100
12.45x12.47	1	2	4	" "	5	11	4 Kahn bars and 11 hoops	155.25	143.4	279,450	1,800
12.45x12.47	1	2	4	" "	5	11	" " "	155.25	144.6	394,000	2,538
12.48x12.49	1	2	4	" "	5	10	" " "	155.88	143.8	296,172	1,900
12.45x12.49	1	2	4	" "	5	10	4 Truscon bars and 11 hoops	155.50	145.8	367,500	2,363
12.02	1	3	6	¾ to 1½-in. trap rock	5	5	None	113.47	146.1	164,100	1,446
12.02	1	3	6	¾ to 1½-in. pebbles	5	3	"	113.47	128.0	143,000	1,260
12.00	1	3	6	Cinders	5	0	"	113.10	101.4	78,900	698

* Exterior Shell. ** Defective column, one hoop displaced during construction.

Table IV.

Description of Column.	Loads after which the curves in Diagram No. 8 were obtained. lb. per sq. in.
1 : 1 mortar	3,500
1 : 1 mortar, 25 hoops, and 4 longitudinal angles	5,700
1 : 2 : 4 concrete, 25 hoops	3,200
1 : 4 : 8 concrete, 25 hoops, and 4 longitudinal angles	2,500

Measurements of the expansion of the hoops of hooped columns during testing showed that adjacent hoops were subjected to very different strains.

Mr. Howard's conclusions derived from the results of the above tests are that sufficient evidence has been obtained to show that high ultimate strength in columns may be reached by each of the three current methods of practice—that is, by the use of rich mortars or concretes, by employing sufficient longitudinal metal reinforcement, and by means of adequate hooping or other external lateral support. Rigidity of columns will be attained by the employment of rich mixtures or by the means of longitudinal bars. The rigidity of mortar or concrete columns is effected practically only by the use of rich cement mixtures. Economy of cost, to attain compressive strength, within certain limits, will be promoted generally by the plentiful use of cement.

Table V. gives the details of some columns recently tested and their ultimate resistances.

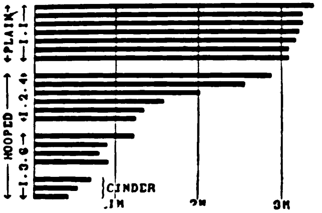


Diagram No. 7.

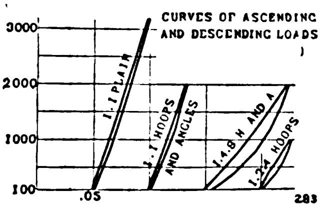


Diagram No. 8.

SOME TESTS AT ZURICH.

The Views of Herr Probst.

Reported in "Das Zusammenwirken von Beton und Eisen."

(The Concurrence of Concrete and Steel) by Emil Probst (Berlin, Wilhelm Ernst and Sohn, 1906. 60 *pp. with photograph and diagram.)*

There is no more disputed question among those with which the reinforced concrete engineer has to concern himself than that of the mode of interaction of the concrete and the steel reinforcement. Great uncertainty prevails as to the nature and magnitude of the "adhesion" or "resistance to slipping," and there is a corresponding want of agreement in the modes of calculation adopted by different experts. The pamphlet of which we are speaking contains the results of an important series of experiments made by the author in the Federal Testing Station at Zürich. Earlier experiments in this direction have usually been made by pulling or pushing a steel rod embedded in concrete and measuring the resistance offered. This does not correspond with the conditions which obtain in practice, when the stresses are taken up by both the steel and the concrete. The experiments were made by bending reinforced concrete beams, the testing machine described by Prof. Schüle (this volume, p. 376) being used. Preliminary determinations of the strength and elasticity of the steel and concrete used were made.

The author's conclusion is that there is no adhesion, properly so-called, between concrete and steel. Their connection is purely mechanical, due to the shrinking of the concrete on to the reinforcement. When cracks appear, the hold of the one material on the other is locally destroyed, and when actual slipping takes place the beam breaks. The figures commonly given for the "adhesion" do not express any definite physical quantity, and vary greatly under different conditions of experiment. Any mechanical means which increase the hold of the concrete on the reinforcing rods increase the strength of the beams. Thus anchoring the ends of the rods or roughening their surface (even by using steel roughened by rusting) increases the strength. Steel rods of undulating or other variable section are, therefore advantageous.

An important practical conclusion of the author is that greater importance than is usual should be attached to the value of the tensile strength of concrete, since the point at which the first cracks appear is dependent on this. Reinforcement should consist rather of a considerable number of small rods than of a smaller number of thick rods, the former offering a greater surface in proportion to their cross-section.

The pamphlet contains a large amount of experimental material, clearly summarised in the form of tables and curves

CORRESPONDENCE.

Under this heading we invite correspondence.

REINFORCED CONCRETE AND THE LOCAL GOVERNMENT BOARD.

SIR,—It has recently come to my notice that the attitude taken by the Local Government Board respecting proposed works, such as tanks, reservoirs, etc., constructed in reinforced concrete, is somewhat unusual. In some cases they have granted thirty years (the usual period for ordinary methods of construction) for the repayment of the loans, but in recent cases this, I notice, has been limited to fifteen years. Reinforced concrete is somewhat different from ordinary methods of construction, inasmuch as if there is any failure it will exhibit itself immediately, and thus one knows from the commencement whether there is any defect in the structure. For instance, if there is any failure or weak spot in such a reservoir, the first time it is filled any such defect will at once show itself; while, on the contrary, if the construction is sound I can see no reason why the period for the repayment of the loan should be limited to fifteen years, because if the structure will safely stand for fifteen years it will stand equally well for fifty, as we know the strength of reinforced concrete tends to increase with age. It would be interesting if this matter could be taken up with the Local Government Board, so that some uniform basis in connection with the repayment of loans for such work may be arrived at. As a very considerable amount of work is now being done, and more will certainly be done in the future, this is a subject which affects all of us considerably, and one to which I think early attention ought properly to be given. I enclose my card, and am,

Yours faithfully,
"INTERESTED."

COLOURS FOR CEMENT AND CONCRETE WORK.

SIR,—In reply to several inquiries as to the best methods of obtaining reliable colours for cement and concrete work, I have given the following particulars as to how to obtain: red, yellow, blue, green, chocolate, black, white. To save myself further correspondence, I should much appreciate your publishing these particulars in your esteemed journal. I think they might be of service to your readers.

RED.

87 parts fine ground Portland cement.
11 ,, oxide of iron.
2 ,, black oxide of iron or copper.
100

YELLOW.

84 parts fine ground Portland cement.
14 ,, yellow oxide of iron.
2 ,, black oxide of iron or copper.
100

BLUE.

80 parts fine ground Portland cement.
18 ,, azure blue or ultramarine.
2 ,, black oxide of iron or copper.
100

GREEN.

85 parts fine ground Portland cement.
12 ,, oxide of chromium.
3 ,, black oxide of iron or copper.
100

CHOCOLATE.

88 parts fine ground Portland cement.
6 ,, black oxide of manganese.
4 ,, red oxide of iron.
2 ,, black oxide of iron or copper.
100

BLACK.

87 parts fine ground Portland cement.
13 ,, black oxide of manganese or any carbon black.
100

WHITE.

67 parts fine ground Portland cement.
33 ,, powdered chalk or sulphate of barytes.
100

Yours truly,
F.C.S.

ARTICLES AND PAPERS

AT HOME AND ABROAD.

The following articles and papers are among the most important published at home and abroad during December, 1906, and January 1907:—

I.—CONCRETE CONSTRUCTION.

Articles.

Concrete Bridge at Neckargartach.—*Zement u. Beton*, 15.12.06.

Concrete Railway Tunnel at Grunewald, near Berlin. By A. Bumann.—*Zement u. Beton*, 15.12.06.

II.—REINFORCED CONCRETE CONSTRUCTION.

Articles.

A Reinforced Concrete Bridge on Swampy Soil: a bridge of three spans over the Gudenaa, near Langaa, in Denmark.—*Beton u. Eisen, Jan.*, 1907.

Reinforced Concrete Reservoir at Waltham, Mass.: *ill.—Eng. Record, Jan.*, 1907.

The Calculation of Freely Supported Reinforced Concrete Panels. By Prof. G. Ramisch.—*Zement u. Beton*, 15.1.07.

A Reinforced Concrete Factory—*Deut. Bauzeit.*, 29.12.06.

A Marine Dam of Reinforced Concrete. By Dr. L. R. de Muralt: details of the construction of a marine dam to the north of the island of Schoumen, Holland, subjected to considerable wave action.—*Beton u. Eisen, Jan.*, 1907.

The Calculation of Reinforced Concrete Panels with Double Reinforcement. By Prof. G. Ramisch.—*Zement u. Beton*, 1.12.06.

Reinforced Concrete Bridge at Ulm. By — Neuffer, Stuttgart: with a plate and *ill.—Deut Bauzeit.*, 9 and 23.1.07.

III.—STEEL CONSTRUCTION.

Article.

Novel Cantilever Construction, the Queen's Hotel, Birmingham.—*The Builders' Journal, Dec.*, 1906.

IV.—SPECIAL SUBJECTS.

Articles.

Application of Spirally Reinforced Concrete in the Construction of the Menier Chocolate Works at Noisiel-sur-Marne, near Paris: this large building rests on a reinforced-concrete pile foundation. The columns are enlarged conically at their junction with the sole. The building also includes a bridge of two 44 metre spans, connecting two parts of the factory on opposite sides of the river.—*Beton u. Eisen, Dec.*, 1906.

New Mode of Connection for Concrete Pipes. By R. Saliger: the ends of the pipes interlock slightly to prevent vertical displacement, and a half-round groove is formed in each face. When fitted together, these grooves form a tubular channel, which is filled with molten asphalte through suitable openings, thus forming a watertight joint.—*Beton u. Eisen, Dec.*, 1906.

Reinforced Concrete in a Canadian Machine Shop Plant: *ill.—Eng. News., Dec.*, 1906.

Decorated Reinforced Concrete Ceilings. By — Gehler.—*Deut. Bauzeit., Dec.* 29, 1906.

Messrs. R. M. Rohrer's Printing Works at Brunn (Austria). By Rob. Deifel: this large building, the first to be constructed in Austria with spirally reinforced concrete, is fully described with detailed drawings and tables of loads and reinforcement.—*Beton u. Eisen, Jan.*, 1907.

New Methods of Manufacturing Concrete Products.—*The Builder, Dec.*, 1906.

The Construction of the Pennsylvania R. R. Tunnels under the Hudson River at New York City. By James Forgie: *ill.—Eng. News, Dec.*, 1906.

New Experiments with Reinforced-Concrete Columns at Lemburg. By Dr. M. R. von Thullie. —*Beton u. Eisen, Dec.*, 1906.

Bridge at Montbrillant By A. Robert: detailed drawings and reports of tests of a large railway bridge in reinforced concrete on the Swiss Federal Railway at Lausanne.—*Beton u. Eisen, Dec.*, 1906.

Unusual Details of a Reinforced Concrete Floor: *ill.—Eng. Record, Dec.*, 1906.

The Influence of Variable Section on the Bending Moments of Continuous Beams, with Special Reference to Reinforced Concrete Construction. A mathematical paper, by Dr. Frank.—*Beton u. Eisen, Dec.*, 1906.

An Architectural Style for Reinforced Concrete. By Prof. Hugo Hartung: an *ill.* account, with architectural and constructional details, of the recently-erected church of St. Jean de Montmartre, Paris, in which an attempt has been made to express the mode of construction in the architectural style of the building.—*Deut. Bauzeit.*, 23.1.07.

The Strengthening of Foundations by means of "Hanging" Piles. By Ottolear Stern.—*Beton u. Eisen, Jan.*, 1907.

SOME SUBJECTS DEALT WITH IN No. 6.

Reinforced Concrete in Italy.
Steel and Concrete at the Ritz Hotel, London.
The New French Rules as to Reinforced Concrete.
Reinforced Concrete Gasholder Tank.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume II. No. 2. MAY, 1907.

EDITORIAL NOTES.

LOANS ON PUBLIC WORKS IN REINFORCED CONCRETE.

From numerous correspondents connected with municipal works we have received further complaints regarding the extraordinary anomaly in the practice of the Local Government Board, in occasionally only granting loans for 15 years in cases where reinforced concrete is used, while on other occasions the ordinary period of 30 years is allowed.

As before indicated, the 15-year period is a quite impracticable one, and we can think of no reason, if reinforced concrete construction is allowed at all for work built with municipal money—as, of course, it must be—why there should be any differentiation between this very practicable monolithic form of construction and ordinary building methods.

We have dealt with the subject before, and do not wish to labour the point, but there is certainly considerable feeling on the matter, and more especially in the North of England, where the Local Government Board is apparently preventing the municipalities from putting up their work in this most economical and up-to-date manner, owing to these occasional extraordinary restrictions as to period of loans where reinforced concrete is used. Surely it must be understood by those in authority under the Local Government Board, that if reinforced concrete passes its tests undertaken upon completion of the work, all that can be expected is greater strength, and not lesser strength and stability, as time goes on.

We of course assume good design, good materials and careful supervision of workmanship, so that the metal rods contained in reinforced concrete work should not be subject to the possibilities of corrosion; but it is just for municipal work that good design should be obtainable, and that supervision can, if anything, be more systematic than in private work.

We think it is time the matter should be taken up in the House of Commons.

THE STABILITY OF CONCRETE UNDER EARTHQUAKE SHOCK.

As in the case of the San Francisco disaster, so at Kingston (Jamaica), have concrete and reinforced concrete proved themselves to be most useful acquisitions in building construction for localities in which earthquakes are of frequent occurrence. The utility in this direction is specially recorded in respect to a residence built at Kingston for Mr. Alfred Mitchell by a firm of contractors from Boston, U.S.A., concrete and reinforced concrete having both been used in this structure.

Here, although water in the baths and tanks was splashed over the sides of these receptacles by the shock, indicating the severity of the vibration, and the rooms containing such baths and tanks were, in fact, partially flooded, not a single crack or fissure was to be found in the concrete and reinforced concrete portions of the building.

The concrete was mixed in the following proportions:—1 part of cement to 3 of sand to 6 of stone, the stone broken to pass a 1½-in. mesh, while the sand was not very sharp and the water used was salt. The concrete was thus none too perfect, and yet excellent results were obtained.

CONCRETE AND THE REBUILDING OF RUINED CITIES.

From various sources we learn that in cities which have been affected by the sequence of earthquakes during the past year, practically all the leading architects and engineers are considering the application of reinforced concrete for new buildings intended to be permanent.

The rebuilding of cities affected by earthquakes must necessarily be slow, more particularly as in many instances the earthquake clause in the insurance policies has made it difficult for property owners to get any compensation for loss incurred by fires arising directly or indirectly from shock, and of course a very large proportion of the buildings destroyed by these earthquakes showed the combined effects of fire and shock.

But when the rebuilding period really commences, as may be anticipated towards the end of this year or beginning of next, reinforced concrete will probably be brought very much to the fore in San Francisco, Valparaiso and Kingston (Jamaica).

With this special demand for reinforced concrete there will naturally go hand-in-hand a demand for Portland cement and steel bars of small section, and it is to be anticipated that this demand in distant lands will affect the prices of both these commodities in the home country, more particularly in respect to the first-class qualities of these materials.

INTERNATIONAL COMMISSION OF REINFORCED CONCRETE.

WE welcome with pleasure the announcement of the constitution of an International Commission of Enquiry into Reinforced Concrete, the proposed institution of which we announced last autumn.

There is no structural subject at the moment that requires greater attention than that of Reinforced Concrete, and it is by international co-operation alone that a true picture can be obtained of what is being done in the different countries, and above all what has been the experience, both in a positive and negative sense.

The Commission, which will have as chairman that eminent authority on all matters of reinforced concrete, Mons. Considère (until lately an Inspector-General of Public Works in France), will further have as vice-chairmen, Professor F. Schüle, Director of the Testing Station of the Zürich Polytechnic, and Privy Councillor Germelmann, of the Ministry of Public Works at Berlin.

The other members of the Commission we name in alphabetical order, and it is a sign of the high importance attached to the subject to observe the status of the members of this Commission:—

Herr Bürstenbinder, Building Police Surveyor, Hamburg.

Prof. N. Belelubsky, Director of the Technical Laboratories, St. Petersburg.

Mr. Max Clarke, Vice Chairman, Science Committee, of the R.I.B.A., London.

Mons. P. Christophe, Principal Engineer, Office of Works, Brussels.

Prof. Canevazzi, Engineering School, Bologna.

Mons. Droujinine, Polytechnic Institute, St. Petersburg.

Dr. von Emperger, Editor of *Beton u Eisen*, Vienna.

Mons. Feret, Chief of the Technical Laboratories, Boulogne.

Capt. T. Grut, Military Engineers, Copenhagen.

Prof. C. Guidi, Engineering School Turin.

Herr. A. Hüser, Civil Engineer, Germany.

Prof. B. Kirsch, Royal Technical College, Vienna.

Dr. A. Martens, Principal of the Prussian Testing Laboratories, Berlin.

Prof. J. Melan, Royal Technical College, Prague.

Prof. Mesnager, Director of the Technical Laboratories, Paris.

Prof. Desiderius Nagy, Royal Technical College, Budapesth.

Prof. Samuel Pecz, Royal Technical College, Budapesth.

Mons. Rabut, Engineer to the Office of Works, France.

Mons. S. J. Rutgers, Municipal Engineer, Rotterdam.

Mr. Edwin O. Sachs, British Fire Prevention Committee, London.

Prof. E. Suenson, Royal Technical College, Copenhagen.

Mons. J. Schustler, Contractor, Budapesth.

Sig. Segré, Chief Engineer to the Railway Testing Laboratories, Rome.

Prof. A. N. Talbot, University of Illinois, U.S.A.

Mons. Tricon, of the Reinforced Concrete Contractors' Society, Paris.

Prof. W. H. Warren, University, Sydney.

Herr E. Züblin, Civil Engineer, Strassburg.

Dr. R. Zielinski, Tutor at the Royal Technical College, Budapesth.

The Principal of the Highways Office, Christiania.

THE REINFORCED CONCRETE COMMITTEE FORMED BY THE R.I.B.A.

To those interested we would record that the report of the Joint Committee on Reinforced Concrete, formed by the Royal Institute of British Architects, is to be presented to that body on May 27th.

THE SPECIAL COMMISSION ON CONCRETE AGGREGATES.

We have been given to understand that the enquiry of the Concrete Aggregates Commission, formed by the British Fire Prevention Committee, has commenced, and that the Commission's work has been divided into two sections in charge of two Sub-Committees, the one dealing with Specifications and the other with Research Work and Tests.

The constitution of the Committee, which has been formed from among the members and subscribers to the British Fire Prevention Committee, is as follows:—

Chairman: Sir William Preece, K.C.B., F.R.S., Past Pres. Inst.C.E., late Chief Engineer, General Post Office.

Deputy Chairman: Mr. Edwin O. Sachs, F.R.S. Ed.

Chairman of Research Sub-Committee: W. T. Hatch, M.Inst.C.E., Chief Engineer (representing Metropolitan Asylums Board).

Chairman of Specifications Sub-Committee: Max Clarke, F.R.I.B.A.

Hon. Secretary: Mr. Matt Garbutt, F.R.I.B.A., A.M.Inst.C.E.

Representing the Admiralty: C. H. Colson, M.Inst.C.E., Supt. Civil Engineer.

Representing the War Office: Col. A. H. Bagnold, R.E., Supt. of Building Works at Woolwich; Major R. N. Harvey, D.S.O., R.E.

Representing the Norwich Corporation: A. E. Collins, M.Inst.C.E., City Engineer.

H. K. G. Bamber, F.C.S., Cement Manufacturer.

F. S. Capon, Assistant Architect, London County Council.

J. Herbert Dyer, Senior Vice-president, National Fire Brigades' Union.

F. W. Hunt, F.R.I.B.A., Surveyor, Portman Estate.

W. H. Hunter, M.Inst.C.E., Chief Engineer, Manchester Ship Canal Company.

Ellis Marsland, District Surveyor (Hon. Sec., British Fire Prevention Committee).

E. G. Rivers, M.Inst.C.E., Chief Engineer, H.M. Office of Works.

Jos. Randall, A.M.Inst.C.E., Contractor.

A. Ross. M.Inst.C.E. Chief Engineer, Great Northern Railway.

J. W. Restler, M.Inst.C.E., Deputy Chief Engineer, Metropolitan Water Board.

James Sheppard, A.Inst.E.E., Chief Surveyor, North British and Mercantile Insurance Co.

Frank Sumner, M.Inst.C.E., City Engineer, Corporation of London.

J. Winn, Lieut.-Colonel, R.E. late of School of Military Enginering, Chatham.

Chemist to the Commission: Mr. Cecil H. Desch, D.Sc., Ph.D.

OBITUARY NOTICES.

Since our last issue appeared two of the founders of the British Cement Industry have passed away.

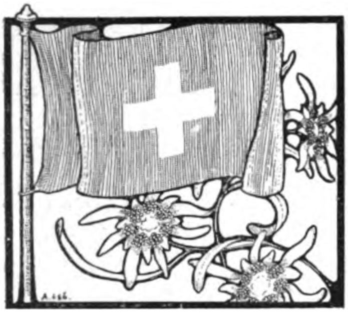
The first was Mr. Thomas Bevan, J.P., D.L., of Stone Park, Greenhithe, Kent, who died on the 1st March, at the age of 78 years. Mr. Bevan was one of the original partners in Knight, Bevan & Sturge, one of the first firms founded solely for the manufacture of Portland cement. Their works are situated at Northfleet, Kent, and are now owned by the Associated Portland Cement Manufacturers, Ltd. For many years Mr. Bevan had been one of the captains of the cement industry.

The deceased became Sheriff of London in the year 1877-8, and was elected M.P. for Gravesend in the year 1880, but was unseated on petition shortly afterwards, and made no further attempt to enter Parliament. For some time past he had, unfortunately, been more or less of an invalid.

Within three weeks of Mr. Bevan's death there passed away another veteran of this industry—Mr. W. Curling Anderson, J.P., who, over a long period of years, was a partner in the well-known firm of Hilton, Anderson & Company, who commenced manufacturing Portland cement as long ago as 1849, and at the time of his death was a vice-chairman of the Associated Portland Cement Manufacturers, into whose hands this business passed in 1900.

No broader-minded business man was ever found in the ranks of the British cement industry. His straightforwardness, energy and sound judgment were proverbial, and there were few men who possessed in a greater degree the confidence of the members of the technical professions.

Mr. Anderson's activities were not confined to business affairs, and he took a prominent part in the political life of the country. He was one of the founders, and for many years the chairman, of the City Liberal Club, and vice-chairman of the Executive Committee of the National Liberal Club up to the time of his death. Although in feeble health for some time past, his interest in business and political affairs remained keen and active to the last.



The Historical Evolution of Reinforced Concrete in Switzerland.

By PROFESSOR F. SCHÜLE, ZÜRICH.

In continuation of our series dealing with the Evolution of Reinforced Concrete in different countries, we now present an article by Professor Schüle, on the development of this system of construction in Switzerland.

There is much in this article that should be of interest in countries where the question of regulating the uses of Reinforced Concrete is, at present, under consideration, and it is pleasant to observe how Scientists, Civil Engineers and Contractors appear to have been working hand in hand with the view of usefully extending this form of construction to meet local requirements.

The author of the article, Professor Schüle, presides over one of the best equipped testing laboratories in Europe, that of the famous Polytechnic at Zürich, and his contributions to the subject of Reinforced Concrete, and his painstaking investigations are known throughout the world.—ED.

THE first Swiss applications of iron rods and wires for the reinforcement of concrete on Monier's system date back to the eighties, only small vaultings were then so treated; the first appearance of reinforced concrete beams subjected to bending was in 1892, and was due to the persistent activity of the representative of the Hennebique firm, Mr. S. de Mollins, of Lausanne. Some successful experiments with plate beams in the presence of representatives of the railways and of the municipal authorities, and the granting of licences to different contractors in the principal towns of Switzerland, to carry out the system in question, soon aroused general interest among architects, then among practical engineers, and by and by also among men of science. The way in which the material was advertised in the earlier years tended to repel some, until the undeniably good results of the work executed brought about general confidence. For some years contractors were entirely dependent for systems and modes of calculation on the improvements introduced in France and Germany, but before long independent firms and engineers so far developed as to labour successfully on their own initiative at the improvement of reinforced concrete, and were able to design and execute the most varied applications corresponding with the needs of the country.

Two conditions have favoured the development of the new mode of construction; firstly, the special conditions of Switzerland, which needs to supply its demand for iron by importation from the neighbouring States, especially from Germany—reinforced concrete involves a saving in iron not to be undervalued—and secondly, the excellent position of the manufacture of hydraulic cements, and especially of Portland cement, here alone to be considered. Since the foundation of the Federal Material Testing Station at Zürich, its former director, Prof. L. v. Tetmajer, endeavoured by means of exhaustive experiments not only to improve the methods of testing hydraulic cements, but also to bring about agreement between producers and consumers, the latter represented by the Association of Swiss Engineers and Architects, as to the description and testing of limes and cements. The standard specifications, which have been several times revised in accordance with the progress of the industry, the last time being in 1901, have provided a very firm and secure basis for the utilisation of Portland cement in reinforced concrete construction, a fact which has contributed notably to facilitate the introduction of the system. As indicating the progress in the manufacture of Portland cement it may be mentioned that the old standards demanded a minimum tensile and compressive strength of 16 and 160 kg. per sqr. cm. from a 1:3 mortar, rammed, after 28 days; whilst the 1901 standard demands 22 and 220 kg.per sq. cm., figures which are notably exceeded by all Swiss Portland cement factories.

The certain application of a new building material demands a uniform method of calculation, even though the latter may have some defects, which find their correction in the permissible limits of stress; such a method was published by Prof. Dr. W. Ritter in 1901 in the *Schweizer Bauzeitung;* it rests on the assumption that reinforced concrete is an elastic material, in which the stresses are distributed between steel and concrete in the proportion 10:1, this assumption is known to correspond with the first stage of loading, before cracks appear in the tension zone, with sufficient accuracy. But in order to take into account the appearance of cracks and the consequent increased load thrown on the steel, the tensions in the steel are calculated neglecting the influence of that part of the concrete under tension.

The calculation of the shearing stresses was only outlined; in the early period of application it was not customary to devote much attention to this. Ritter's method had the great advantage of introducing uniformity into the determination of the position of the neutral line.

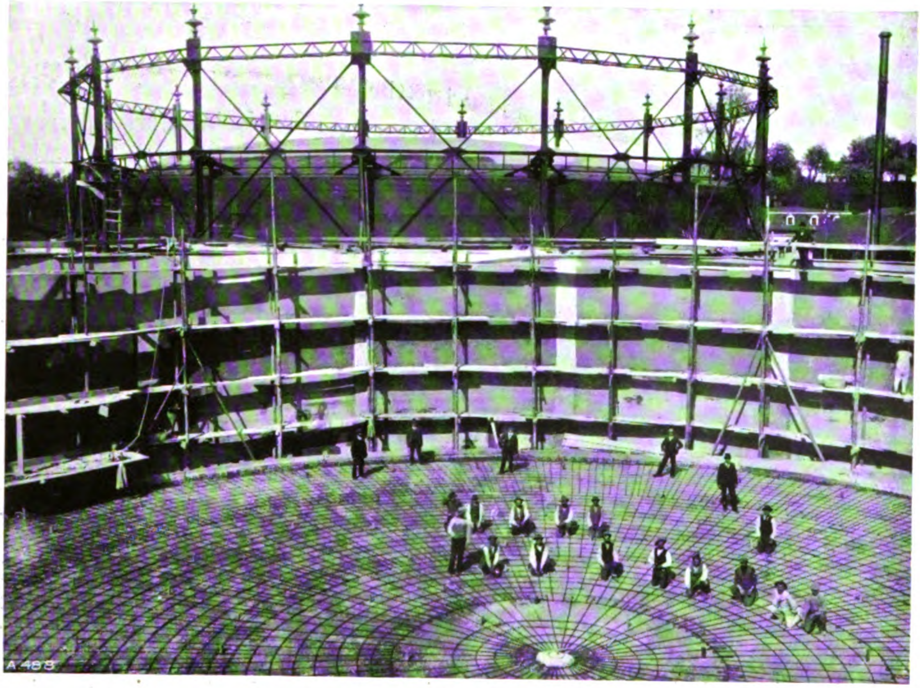
Accidents at home and abroad indicated the necessity of rules for reinforced concrete, to be enforced by the building authorities. An enquiry by Herr Reese, of Basle, among the building authorities of German towns, showed how great was the divergence of the different rules; in 1902, a report by Herr Geiser, Prof. Ritter, and the author, enabled the establishment of a basis of official control—which should not hinder the new industry, and should yet meet the requirements of the public security.

The Association of Swiss Engineers and Architects then invited the different cantonal sections to furnish proposals for regulations, and the replies were in the hands of the committee at the beginning of 1903; St. Gallen, Neuchâtel and Geneva, favoured quite general regulations; Basle, Berne, Freiburg, Waadt, and Zürich made definite proposals. These were considered, and all proposals on which there was agreement were adopted, whilst others were abandoned, either because the points considered were insufficiently clear, or because they entered into details which would have extended the specifications unnecessarily.

The results of this revision were issued by the Association of Swiss

Engineers and Architects in August, 1903, under the title "Provisional Rules for the Design, Execution, and Control of Works in Reinforced Concrete." The main difference between the method of calculation and that of Ritter consisted in the ratio *n* of the stresses in steel and concrete being taken as 20. This figure is rather high for columns or for concrete subject to pressure; experiment is known to give a value of about 10; the higher figure is justified by taking account of the permanent strain in the concrete.

The stresses permitted are in concrete, 35 kg. per sq. cm., under compression, and 4 kg. per sq. cm. under shear; for steel, 1,000—1,200 kg. per sq. cm., under tension, and 700 kg. per sq. cm. under compression.



Two Gasometer Tanks at St. Gallen.
(Constructed in 1903-4 by Messrs. Maillart & Co., Zurich. Diameter 40 metres, depth 9 metres.)

The theory is not applicable to its full extent to continuous beams of reinforced concrete; on account of the permanent deformations after loading, and on shrinkage of the concrete, a correction of the usual theory is necessary. The Swiss rules prescribe that for freely supported beams the bending moment in the centre is not to be reduced by the full amount of the supporting moment, but by only two-thirds of this value. So, with fixed ends, the moment in the centre is not $\frac{pl^2}{24}$, but $\frac{pl^2}{14 \cdot 4}$, which corresponds with an increased factor of safety.

These rules have no official character, but nevertheless they supply the standard for all building authorities for the execution of buildings and road bridges, and are introduced into most contracts.

Reinforced concrete is only used for railway bridges in special cases, where the span is small, as in subways and aqueducts; the as yet unexplained influence of cracks in the tension zone, and of vibration due to the passage of heavy trains, has led to the introduction, in 1906, by the Federal Railways Department of Berne, of rules which are decidedly more stringent than the provisional rules mentioned above.

A single large railway bridge has, so far, been constructed in reinforced concrete, for an industrial line to an aluminium works at Chippis, the span being 60 metres. This bridge consists of a bowstring of two parts, rectangular in section, and carrying a suspended roadway, also of reinforced concrete. This work affords an opportunity of collecting information as to this application; the contractors were Messrs. Froté, Westermann, and Co., Ltd., of Zürich. An exhaustive loading test was carried out in December, 1906, under the direction of M. Rabut, of Paris.

In the rebuilding of railway stations at Olten and Lausanne, reinforced concrete was used for passenger subways; at Olten these have been used for ten years without showing any defect.

The establishment of rules has not in the least resulted in any lessening of interest in the scientific explanation of the many new questions connected with this material; the need of further investigation in this direction exists more and more, and the parties interested have aimed since 1899 at the establishment of an official commission for the study of reinforced concrete. These steps were not crowned with success until 1905, when the Federal Department of the Interior established a commission, consisting of representatives of the Department, of the Association of Swiss Engineers and Architects, of the Swiss Portland Cement Manufacturers, of the municipalities, and of the Railway Department. A period of three years is allowed for these investigations, which are to aim at the drawing up of official regulations.

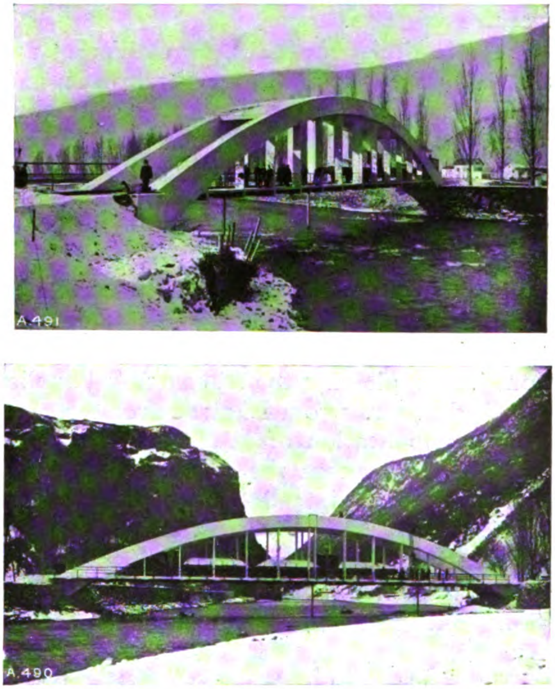
PROTECTING WALL AT TIEFENKASTELL ON THE RHAETIAN RAILWAY.

(Constructed by Messrs. Maillart & Co., of Zürich. Projection 4 metres.)

The experiments were performed in the Federal Material Testing Station at Zürich, which had in 1902 undertaken exhaustive experiments on its own initiative, which were published in Part 10 of its Reports. These tests are characterised by the extensive measurements of the changes of length produced by loading and unloading. A special testing machine, constructed from the author's specification by Messrs. Amsler-Laffon and Son, of Schaffhausen, allows bending tests to be made on a length of four metres, with equal forces applied at seven points, corresponding with a uniform distribution of the load. At the present time, an extensive investigation is in hand of the properties of concrete prepared with 25 kinds of gravel and sand, used in different towns, with the same Portland cement; this is intended to determine the differences due to the gravel and sand.

It would lead too far here to enumerate completely all the systems which find application in works of reinforced concrete; the spirit of invention finds ample scope in this region, and, further, the differences between one system and another are mostly of minor importance, and the protection by patent illusory.

The conviction gains ground more and more that care in the design and execution plays a more important part than the special arrangement of the subordinate parts of the reinforcement. All the modes of reinforcement in use in Switzerland have in common the use of round steel rods for the main reinforcement; where the greatest bending moments occur, these rods lie as close to the surface of the part under tension as possible, where also great shearing stresses occur, some of the rods are bent up at an angle, usually of 45 deg., all at the same distance from the centre, as in the Hennebique system, or at different points, as in the system of Messrs. Maillart and Co., of Zürich.



BRIDGE OVER THE RHONE AT CHIPPIS.

(60 metres span, with suspended track in reinforced concrete—built by Messrs. Froté, Westermann & Co., of Zürich.)

Hennebique stirrups, of vertically-arranged flat iron, or of round iron, vertical, or rising, or alternately rising and falling, are used. It has also been attempted to bend the ends of the reinforcing rods, according to the theoretical direction of the tensile stresses, to cross the horizontal axes at an angle of 45 deg., and to place them vertically in the compression zone

(Locher system), but the applications of this mode of construction have been isolated.

In columns, the reinforcement is almost invariably formed by vertical round steel rods, with cross connections of hoop iron or wire at a distance apart equal to the breadth of the column; the Considère "béton fretté" is only occasionally used, as the additional cost of reinforcement cannot be compensated for in columns by a corresponding economy of concrete without bringing about excessively high compressive stresses, which can only be permitted in special cases, on account of the great importance of massive columns.

As in other countries, two different modes of procedure exist, either the design is prepared at a central office, and contractors execute the work. or firms undertake both the design and the execution. All experience of recent years favours the latter method, by which the responsibility is exactly fixed; on the first method there is too often a lack of understanding of the execution on the part of the designer, and a lack of comprehension of the plans delivered to him on the part of the contractor or licensee.

Some of the latter, however, have accumulated great experience, and have accustomed themselves to follow the plans given them strictly; and the care taken by some designers to prepare their designs in great detail, and to leave nothing to the judgment of the contractor, must here be mentioned, as explaining the still extended application of the system of licences.

Eight years ago a Lucerne architect, Herr Siegwart, introduced a new mode of application of reinforced concrete, avoiding construction on the building site, except the actual laying of the prepared beams. It is true that this is only intended for reinforced concrete floors, and with a span hardly exceeding five metres, but the principles put forward are excellent.

It would lead too far to attempt to give a survey of the interesting applications of reinforced concrete in Switzerland; the most numerous of these concern building, and include hotels, warehouses, schools, factories, locomotive and tramway depots, theatres, houses, and business premises.

In constructional engineering, we have, besides the bridges, which must receive separate notice, aqueducts for water power installations, caissons for pneumatic foundations, protecting walls against falls of snow, stones, and rock at exposed sections of railway lines, gasometer tanks, foundations in bad ground, and poles for electric power wires.

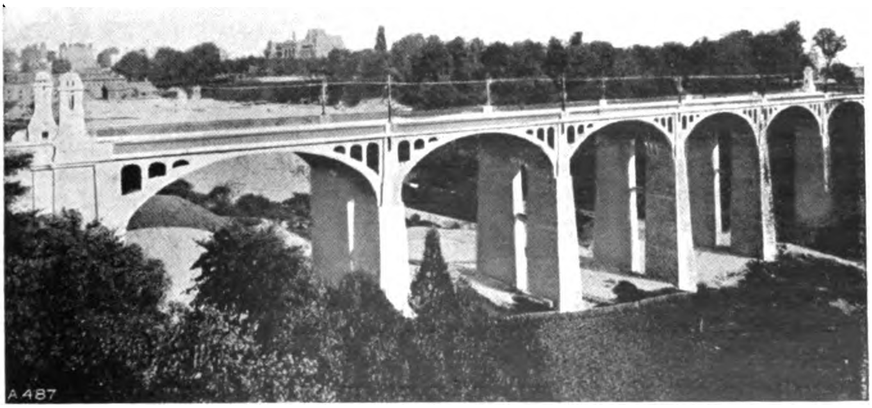
The construction of bridges has always occupied a foremost place in constructional engineering in Switzerland, and the applications of concrete in this department in the last 15 years have been numerous. Railway bridges have been already referred to; for road bridges, reinforced concrete first came into extended use for decking under macadam or asphalte, as in the reconstruction of the Mont Blanc bridge at Geneva in 1902.

In the competition for the Chauderon-Montbenon bridge at Lausanne, a design of a reinforced concrete bridge on the Melan system was ultimately successful; this was constructed in 1904-5, the annexed illustration is supplied by the contractors, Messrs. de Vallière, Simon, and Co.

Several road bridges have been constructed in recent years as light arches up to 51 metres span, with or without hinges. Designs for reinforced concrete bridges appear in every competition, and their decoration differs markedly from those hitherto employed; a new style is coming into use.

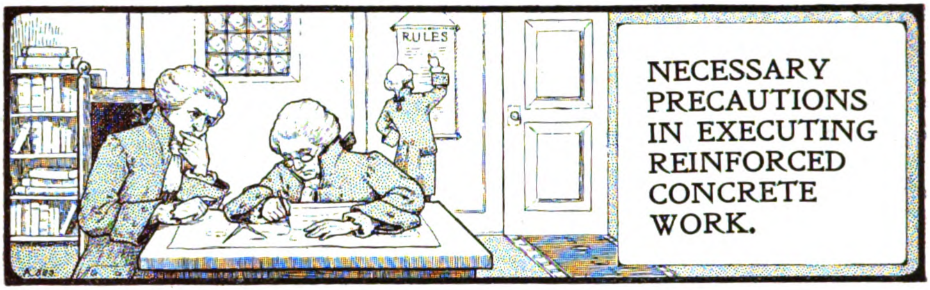
Such a survey would be incomplete without mention of the names of the Swiss engineers most actively associated with reinforced concrete work. Besides Mr. S de Mollins, of Lausanne, already named, there are Messrs. R. Maillart, Froté, Jäger, and Locher, all of Zürich; G. Meyer, of Lausanne; Münch and Pulfer, of Berne; and E. A. Westermann, of St. Gallen, who concern themselves both with design and execution, *i.e.*, also act as contractors.

Engineers who have been actively concerned with reinforced concrete as representatives of authorities, or from a scientific point of view, are, among others, Messrs. Elskes, of Berne, and Vaulier, of Lausanne, who are also active as authors. The new mode of construction has also been introduced into the programme of lectures at the technical schools; special courses are given by Prof. Mörsch and Herr Thurnherr, at the Zürich Polytechnic, and by Messrs. Lossier and Paris at the University of Lausanne; but owing to the still insufficient explanation of many questions, the subject is not yet very well suited to the instruction of practical students.



THE CHAUDERON-MONTBENON BRIDGE AT LAUSANNE.

*(**Constructed by Messrs. de Valliére, Simon & Co., on the Melan system.** Dimensions, 6 spans of 28·75 metres each; total length 227 metres; breadth between balustrades, 18 metres; height above valley, 32.6 metres.)*



NECESSARY PRECAUTIONS IN EXECUTING REINFORCED CONCRETE WORK.

By LIEUT.-COLONEL J. WINN, R.E., A.Inst.C.E.
(Late Instructor in Construction, School of Military Engineering, Chatham.)

We are presenting from the able pen of Lieut.-Colonel J. Winn, R.E., a valuable contribution as to the precautions necessary for the proper execution of reinforced concrete work, and we cannot but impress upon those who employ this excellent method of construction how essential it is that every care should be taken.

As we have indicated before, most failures with reinforced concrete work occur during the building operations, and not after the final completion of the structure; thus such failures have almost invariably been due either to unsuitable design or negligence in workmanship, and do not as a rule affect any primary principle upon which reinforced concrete is based.—ED.

THE Technical Press has from time to time brought to notice that failures have occurred—and some of a serious nature—where structures have been executed in reinforced concrete, and this has created in some quarters a feeling of want of confidence in this material, which is rather out of proportion to the real state of the case, for, though it is right that we should frankly acknowledge that failures have occurred, it is well to bear in mind that the number of such is extremely small compared with the cases where this material has been employed with perfect success. These successes, being normal, do not call for any comment in the Press, and so the reading public are not made aware of what is being done on a very extensive scale in all directions, but as soon as a failure happens, this being abnormal, it at once calls forth comment, and thus an impression is formed that this excellent material is unreliable.

Bearing in mind that it has been, and is being, used with perfectly satisfactory results in numerous cases, it seems to be the most reasonable thing, not to reject all further consideration of its capabilities because a few failures have attended its use—or rather mis-use—but to learn from these how to avoid the faults that they have revealed.

It is not always possible to ascertain the cause of failures, for, for obvious reasons, those responsible for them are generally very reticent on the subject, and are not anxious to give that publicity to all the details contributing to the want of success of their undertaking, which would be such a valuable lesson to engineers and others, who could profit from the experience gained, as it is only a truism to say that "we learn more from our failures than from our successes," and it has been well said that "the man who never made a mistake never made anything."

In some countries official enquiries are held, and the results of the enquiries are published for general information when anything of the nature of failure occurs, so that all may benefit by the investigation, but even then it is not always possible to find out contributory causes which may have affected the execution of the work.

"Hustle" may be an excellent principle, but it will be found that this is responsible for much of the trouble, not that rapidity of execution cannot be expected in using reinforced concrete, rather the reverse, as a large number of important structures in this material compare very favourably as to time of execution with similar buildings of other materials, but to instance a general case :—A theatre is being built of this proved fire-resisting combination, a time has been fixed for the opening, the company is engaged, all arrangements are made, the bills are all out, etc., etc.; any delay would mean a financial loss, when those responsible for the work find that the materials being supplied towards the end are not up to the specification, or some mistake has been made in the location of some important member. To wait for a fresh consignment, or to rip out the defective member means delay, but delay spells loss, perhaps serious loss; it is therefore not to be thought of. There is in consequence a tremendous temptation to use the inferior material, or to risk the member being strong enough after all, or if it is decided to replace the member, this means less time for the concrete of the new member to set, before the centering is removed or before the load comes upon it—also a risk. Fortunately we are not given to " hustling"—*i.e.*, to a dangerous extent—in this country, and consequently we find that failures due to this cause are infrequent on this side; but there is little doubt that elsewhere the chief cause must be looked for in this direction.

Again, in these days of keen competition there is a danger to cut down dimensions to very fine limits, and in a case which came recently to the notice of the writer these limits were positively unsafe, and courted disaster, and it is therefore desirable that all designs should be submitted for examination to someone who has made a special study of reinforced concrete, who can offer an independent opinion as to their being equal to the task to be imposed on them.

It will be remembered that in some recent investigations it was found that after designs had been so submitted and approved, in the course of execution of the work there had been a distinct departure from the original drawings, and as these alterations had not been examined, the catastrophe which ensued, involving the loss of several lives, was directly traceable to this cause, showing the necessity for careful supervision to ensure that the approved design is adhered to.

If constant supervision cannot be arranged for, it is well not to embark on reinforced concrete, though this may be equally said of any other kind of construction, and is not peculiar to this special development of engineering, though it is well to emphasize its importance.

Success depends on suitable design, the best of materials, adequate centering, and careful supervision; on the contrary the causes of failure are faulty design, faulty materials or faulty execution, or a combination of two or all of these.

FAULTY DESIGN.

This is due in some cases to want of understanding of the stresses which are produced under the conditions of loading to which the structure will be subjected, and consequent bad arrangement of the reinforcement; there is certainly a combination of steel and concrete, in so far as rods are introduced, and perhaps in ample quantity if they had been properly arranged to meet the stress they are supposed to provide for; but that is just where they are wanting, and though the metal is present it can hardly be said to *reinforce* the concrete, and the whole may be described as a jumble of steel and concrete. As the advantages of reinforced concrete are becoming better known there is a desire to use it, and this produces competition on the part of builders and others to tender and submit plans, which on examination show that whoever is responsible for them has failed to understand the principles underlying the design of such buildings. They probably copy (or " improve ") some drawings they have seen in some paper, without regard to the different conditions which may exist, and as the drawings may appear all right to an inexperienced eye, if their price is right, they get the contract, they complete the work with the best materials, only to find that when the strain comes on the structure it collapses. The only remedy for this is for all designs to be examined by reliable experts, at least till the use of reinforced concrete has become so established and standardized that its principles are as well understood as other forms of construction. This need not deter people from using it now, as there are a number of engineers and architects who have given the question special study, to whom reference can be made.

However, quite apart from absolute ignorance, it is feared that failures have occurred owing to the tendency, due to the very high tests which these materials have stood and which are duly chronicled in the Press, to expect too much from them in practice, and so to design the various members to take a greater stress than is justified by considerations of absolute safety. As this also reduces the cost of the undertaking there is a real temptation, especially when competing with rival systems, to "cut it fine" with the risk of failure as a result.

We know that really surprising results have been obtained with 1 : 3 : 6 concrete, the compression tests giving anything up to 3,000 lb. to the square inch; and so, giving a fairly liberal factor of safety of 5, it is taken for granted that 1 : 3 : 6 concrete may be expected to safely stand 600 lb., and many structures have been designed with this as the co-efficient, and have been satisfactory. But are we justified in accepting this as a safe guide for general practice? When we remember that, though the concrete may stand this in compression, this is not the only thing that we have to consider, for what is of equal importance is the "grip" that the concrete has on the rods, and with this rather "lean" mixture the co-efficient of adhesion, as it is frequently miscalled (it would be better to call it frictional resistance) must be taken very low, and not only so, but the shearing resistance is low also, and if reliance is going to be placed in the concrete to stand the shearing stress (never a very sound thing to do) great risks are incurred in adopting such a mixture as this.

It is therefore strongly urged that 1 : 2 : 4 should be considered as the weakest mixture which may be expected to stand in ordinary practice a stress of 600 lb. in compression, and given that this is made, as will be described, of proper constituents and in a proper manner, we may take this as capable of standing a shear of 60 lb. per square inch, and the frictional resistance between the concrete and the rods as 100 lb. per square inch, though it is always advisable to split and birdsmouth the ends of the rods as well.

In compression members such as columns, where the whole section is exposed to the same stress, the co-efficient should be reduced to 500 lb. for the concrete, and 50 lb. extra for each 1 per cent. of steel of the area of the column, which should be braced when the length is twenty times the least dimension of the column. In columns with 1 per cent. of vertical rods, and "hooped" with spiral wires with a pitch of $\frac{1}{6}$ of the diameter of the column, and aggregating 2 per cent. of the volume, we may raise the co-efficient to 900 lb. to the square inch of the area inside the spiral windings.

These figures refer to the safe stress after twenty-eight days, using stone as the aggregate.

Considering the shearing stress for a minute, there is little doubt that its importance has not in some cases been recognised, and though in floor slabs if they fail at all it will probably be due to the bending stress rather than to shearing; on the other hand in beams, especially if they are rather deep in proportion to their length, and more particularly in **T** beams, there is a danger of their failing from the latter cause.

We have seen that concrete is unreliable when it comes to shearing, so that precautions must be taken to introduce in the right place shear bars to take up this shearing (or the greater part of it), limiting the stress on the concrete to the figures already mentioned, and as in a large number of tests the beams were found to fail from diagonal tension, the best direction for these bars is the same as the tension members in an ordinary lattice girder (the concrete itself being well able to represent the compression members), and the more intimate connection there is between these bars and the main rods the better.

Coming now to the amount of reinforcement that is required in a beam made of 1 . 2 : 4 stone concrete, we must bear in mind that in a number of beams of this class that have been tested to destruction, it was found that with amounts of steel up to 2 per cent. it was the steel that failed rather than the concrete, but the stress at the moment of rupture in the concrete was far in excess of that which we have taken as our safe limit, and it will be found (in the ordinary run of beams where the breadth is about half the depth) that when the concrete is stressed up to 600 lb. with a 1 per cent. reinforcement the stress in the steel will be 12,600 lb. Taking a mild steel with an ultimate strength of 60,000 lb., and an elastic limit of between 30,000 and 35,000, we may consider 15,000 lb. as our minimum safe stress, so that we find that we shall require to balance our concrete rather less than 1 per cent. of reinforcement, and we may take 1 per cent. as a general guide. If we take more than this, and stress it up to 15,000, then the concrete will be stressed above the 600 lb. we have considered safe, and though there is no doubt that it can be stressed above this without failing by crushing, and in very many cases it is undoubtedly stressed above this limit, still there is a consensus of opinion that this figure should not be exceeded in good practice.

In making calculations the tensile resistance of the concrete should be neglected, for, though it, of course, possesses some power of resistance at low stresses, a single crack, which may be expected when the steel is stressed up to 15,000 lb., will vitiate any tensile power it may have had, and any resistance it may have exercised will cease to exist. For this reason any concrete below the reinforcement must not be considered in making our calculations, but must be looked on simply as a covering to protect the steel from the weather, fire, etc., so that the depth of the beam for the purposes of calculation must only be taken from the compression edge to the centre of the reinforcement.

As we have seen, it has been found by experiment that with 1 : 2 : 4 stone concrete, and with reinforcement up to 2 per cent., it is the steel that fails, and not the concrete. The formula given below may be taken to check the moment of resistance of any member subjected to cross bending. It is very simple, and agrees with more elaborate formula, worked out with the resistance of the *concrete* as their basis, on the assumption that the ratio of the modulus of elasticity of the steel to that of the concrete is 15 : 1, and also agrees with the results of a number of tests which have been recently carried out by Professor Talbot to ascertain by actual experiment the location of the neutral axis with varying amount of reinforcement, and as the percentage of reinforcement is never likely to exceed 2 per cent, for the reasons given above it may be taken for general guidance :—

$$M_r = (\cdot 9 - \cdot 04 \times p)\ A\ t\ d.$$

p = percentage of steel of the area of beam above reinforcement.
A = area of steel.
t = stress per unit of steel.
d = depth of beam from the compression edge to centre of reinforcement.

Using this formula, and taking 15,000 lb. as "t," and equating the moment of resistance of the steel with the moment of resistance of the concrete, found by the more elaborate formula which has been accepted by the "Joint Reinforced Concrete Committee" referred to in the January issue of this magazine, and which will soon be in the hands of the public, it will be found that, with the following percentages of reinforcement, the corresponding stress of the extreme edge of the concrete will be in round numbers:—

Percentage of Reinforcement.	Stress in the Concrete.
·75	575 lb.
·8	610 „
1·	720 „
1·5	940 „
2·	1,100 „

From this it will be seen that if we confine the stress on the concrete to 600 lb. there is nothing to be gained by using more than ·8 of 1 per cent. as the reinforcement, but as this amount may be reduced by rust (not that this is likely if the proper precautions are taken), whereas the strength of the concrete increases with age, to balance the two at least 1 per cent. appears to be desirable.

On the other hand, if more than this amount is introduced and the steel is stressed up to its limit of 15,000 lb. we see that the corresponding stress on the concrete will considerably exceed the limit which we have accepted, though it is well to remember that this figure refers to concrete after 28 days, and, as we have seen, its resistance increases with time.

In considering **T** beams it should be borne in mind that the head is already under compression to a certain extent, owing to its action as a slab carrying a load, and therefore, in working out the compressional resistance of the concrete, we must see that the compression due to its acting as the head of a **T** beam, when added to its compression as a slab, does not exceed the limit mentioned above, and if there are cross binders as well as main beams, as there usually are, and these have been calculated as **T** beams, then the compressive stress due to these must also be taken into account, and this must be added to the slab stress and the main beam stress, and the three combined must be within the 600 lb.

It is not wise to consider a greater width for the **T** head than one-third the length of the beam, or three-fourths the distance from centre to centre of the beams, whichever may be the less of these two dimensions, and the leg should be well connected to the head by shear bars going well into the head, as the tendency of **T** beams, which are generally in depth about $\frac{1}{10}$ the span, is to fail by the head being sheared off the leg.

By the latest French Government rules it will be seen that slabs supported on all four sides when square may be considered three times as strong as slabs only supported at the ends. The practice in England up to the present has been to take them as twice as strong. Perhaps a happy medium is wisest in our present state of knowledge. It will, of course, be understood that the same amount of reinforcement will have to be introduced in both directions.

Having touched upon a few elements of design, which, had they been carefully observed, would have prevented more than one fiasco, we will now consider the second cause of failure.

FAULTY MATERIALS.

These are generally to be found in connection with the concrete rather than with the steel, because the steel on the market is generally of the specified quality, though each consignment should be tested. The usual requirement of a 22 per cent. elongation, and a cold bend through 180 deg. to a diameter of the thickness of the piece without fracture, should be complied with.

With regard to the concrete, the most important item, of course, is the Portland cement, and this should be up to British Engineering Standards Committee's specification. To ensure this it must be tested. There is a vast amount of inferior cement on the market, not to mention the dangerous "natural" cement, unfortunately still imported into this country, and such is the demand that even brands of approved reputation may require cooling before they can be safely used in the work, whilst the only real safeguard is to constantly test it, which can be done with very simple apparatus.

The sand should be clean and sharp, and the grains vary in size from what will pass an ⅛-in. mesh up to ¼-in. The graduation of the size of the grains is most important to ensure a thoroughly compact mortar without voids. It has been contended in the technical Press that a certain amount of clayey matter improves the resulting mortar, and the results of tests have been adduced to support this contention, but the desirable amount is so uncertain that it is not considered wise to run the risk of overdoing it, and the better course appears to be to avoid the possible danger by insisting on the sand being clean.

Coming now to the aggregate we must remember that, though we are dealing with concrete, it is not *ordinary* concrete, and it is because this has not been understood there has in some cases been a lack of care in its manufacture, which has led to disappointment in the result, and even danger. What we want for reinforced concrete is a thoroughly well proportioned, compact, solid mass, which can in the process of laying be brought into intimate contact with the rods, and absolutely fill up every hollow, and, when set, be free from all cavities. Up to the introduction of reinforced concrete the making of concrete was more or less of the "happy-go-lucky" kind, and being in large masses small imperfections did not much matter, but with the lighter sections and the heavier strains more care must be taken in its composition and its manipulation. Whatever aggregate we may use (and this depends so much on the locality and purpose of the building that we cannot specify them in detail) it must be broken sufficiently fine to be readily punned into any position in the casing and around the rods. This practically limits the size to ¾ in., and here again we must have every gradation of size from ¼ in. (which we have taken as our limit for sand) up to ¾ in., so that the resulting concrete may be a solid mass without voids.

When thus broken the voids must be carefully gauged, and, bearing in mind that 1 part of cement added to 2 parts of sand will only make 2·3 parts of mortar, sufficient cement (which should be determined by weight to ensure the right quantity, 90 lb. being taken as equivalent to a cubic foot) and sand must be added to fill the voids with an addition of 10 per cent. to ensure that the resulting concrete is a thoroughly solid, compact mass. The amount of water (which should be clean and fresh, not salt) depends so much on the time of year, the temperature, the materials themselves, etc., etc., that it is impossible to specify the quantity that will be required in each case, but it is enough to say here that sufficient must be added to ensure the thorough crystallisation of the cement, and it will also be found that a rather wet mixture is easier manipulated in the casing, though care must be taken that it is not put in *too* wet, or it will not ram well, and the necessity of this cannot be too strongly urged if the resulting concrete is to be satisfactory, for not only does ramming (punning is perhaps a better word, as it implies the use of the special punning tools, which are essential in all reinforced work) consolidate the concrete to the extent of reducing its volume by some 10 per cent., but it drives out all the imprisoned air, and also ensures the concrete finding its way into every crevice between the rods, which will not be the case if the punning is neglected, and instead of a solid mass, a honeycomb will result, which will be deficient both in solidity and "grip." Though this "grip" on ordinary round rods is generally sufficient, and many specialists never think of using anything else, it is well to remember that the whole success of the work depends on this, and if there is the least anxiety in the minds of any designers there are now several excellent deformed rods, such as the "indented bar," on the market that give what is termed a "mechanical bond" over and above the "grip" produced by the setting of the concrete, and mesh reinforcements, such as "expanded metal," act in a similar way.

FAULTY EXECUTION.

We now come to the third cause of failure, and it is evident that the best of designs, and with the best of materials, the result will be unsatisfactory if there is something wanting here. As the writer was saying to an engineer interested in this kind of work, "a fool with a shovel may absolutely defeat the most elaborate calculations involving the Calculus," and it is here undoubtedly we must look for the cause of most of the failures which have been reported from time to time.

To ensure good concrete it is essential that the cement must be allowed to set under the best circumstances, and to ensure this there should be no vibration during the process. It is therefore evident that the supporting centering and sheeting must be sufficiently stiff to prevent it, so that there may be no disturbance when the concrete is once laid, also the centering must be sufficiently strong, so as not to "give" during the process of ramming the concrete, and the casing must also be of the correct size to agree with the plans. This condition is so obvious that some surprise may be expressed that it should be mentioned, but in more than one case it was found on examination of the wreck that the dimensions of the members were considerably less than those of the design, and, strange to say, the difference had not been noticed during construction. Angles should be splayed or chamfered.

The centering must also be designed so that it can be removed without jarring the concrete, and must not be removed till the concrete has set. The time will depend on circumstances, the size of the piece, the state of the weather, the amount of water used in mixing, etc., but eight days is the minimum that the casing should remain in position, and this time should be increased in proportion to the importance of the piece concerned up to 28 days, which should be allowed for arches of large span. If, however, the floor or other portion is to be loaded at once and used for traffic, which is frequently the case, then the centering should remain in position to support it for the maximum period, and if frost should intervene during the setting time, the interval before the centering is taken away should be prolonged to the extent of the duration of the frost.

REINFORCEMENT.

All rods should be unpainted and free from grease. They should be brushed over with a wire brush, and, if possible, washed over with a coat of cement wash. They should be of the section laid down in the plans (this again appears too obvious), and should be arranged in the exact positions set out in the design, in such a way as not to be shifted in the process of laying and punning the concrete (again an obvious necessity), but in a case known to the writer the main rods were left out altogether, and in many cases the shear bars have been omitted, though shown in the design, and, when not omitted altogether, they have been moved out of place in such a way as to be perfectly useless for the purpose for which they are intended.

Where joints occur they should overlap 25 diameters of the rod, and be wired together to prevent the ends being dislocated, and if there are any welds (which, as a rule, should be avoided) these should occur where the stress is least. The ends should be split and opened. The rods should be covered in *beams* exposed to *fire risk* by 2 in. of concrete, in other cases 1 in. will suffice; for *slabs* 1 in. *for fire* and ½ in. for ordinary covering will be enough.

LAYING THE CONCRETE.

Having secured the rods in position, the concrete having been thoroughly mixed (the water being applied from a can with a rose upon it), after seeing that the constituents have been carefully measured in the proportions decided upon (obvious again, but none the less necessary to mention it from cases known to the writer), the concrete should be laid in layers of not more than 3 in., and punned round the rods as stated already in dealing with materials; avoid joints as far as possible, but when work has to be commenced on a surface already set, hack it all over, sweep it clean, and cover it with a coat of cement grout. Before laying the concrete see that all rubbish, such as pieces of wood, shavings, pieces of rag, etc., have been removed from the casing (obvious again). This is most important. Concrete which has partially set on the banker, owing to a break in the work, should not be "knocked up" on resuming and used in work, it should be sacrificed rather than cause a weak spot. This is mentioned as it is a most usual precaution in concrete work, and certain engineers and contractors contend that "it is just as good," but the writer maintains it is a fatal mistake to run the risk of having a weak spot in the comparatively small scantlings which are peculiar to reinforced concrete.

Working in frost should be avoided, and newly laid concrete should be protected from the action of frost; it should also be protected from the heat of the sun, and should be kept wetted.

"WATERPROOF" CONCRETE.

As walls to reservoirs made of reinforced concrete have in certain cases leaked, they must be classed among the failures we are considering, and at the outset it must be recognised that 1 : 2 : 4 : concrete is not proof against a head of water, though it may be amply strong to resist the static pressure.

If special provision of a waterproof layer is not made, not only will the reservoir leak, but the reinforcement will be exposed to the danger of rusting. A layer of two inches of 1 : 1 mortar, or three inches of 1 : 3, if it has a solid backing of 1 : 2 : 4 : concrete behind it, free from cavities, has been found proof against a head of 50 feet. To ensure that there are no cavities the concrete for the backing and the special waterproof layer should be laid at the same time in all vertical work, and thoroughly amalgamated where they join, and in horizontal work the waterproof coat should be laid before the coarser concrete beneath has set, so that the two may be thoroughly blended together. It is not advisable to apply the special coat in the form of rendering, as there is a tendency for it to peel off, and the bond between them is not so good as when they are placed in position at the same time and set together.

As an extra precaution it has been found that mixing 2 lb. of soft soap and 12 lb. of alum, with 30 gallons of water (which is about the amount that is required for a cubic yard of concrete), renders the resulting concrete more waterproof and has no deleterious effect upon its strength.

TESTING.

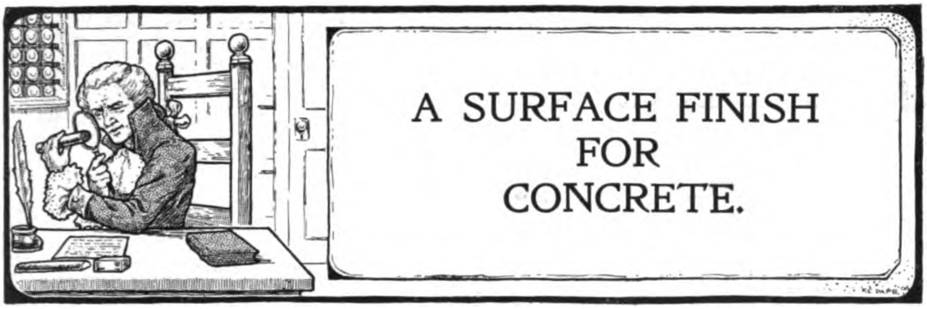
Though we have assumed that the concrete specified in the foregoing remarks will stand the compression, we anticipate this does not do away with the necessity of continually testing specimens during the course of the work. Each consignment of cement should also be tested, and if the work is of an extensive character, and the consignment of cement is large and kept in store for some time, tests should be made from time to time, for though cement generally improves by keeping it *may* occasionally deteriorate, especially in warm damp climates, when it will be found to lose much of its cementitious value.

When the work is completed it should not be tested with the load test till at least two months have elapsed since the concrete was laid, and then the test load should not exceed 50 per cent. more than the member was designed to carry, or otherwise it may be overstrained. If the right proportion of reinforcement has been used this will ensure that it is not strained to more than two-thirds of its elastic limit, an amount which should not be exceeded.

CONCLUSION.

It will be noticed that we have dealt very largely with what may be considered the elementary details in the design and execution of reinforced concrete, but it is just in these particulars that special care must be taken, and it is hoped that no one will be dissuaded from using this excellent combination by the setting forth of the possible reasons of past failures, but rather, being warned by past experience, they will be able to avoid them.

Many of the details touched on have been considered by the "Joint Committee of the Royal Institute of British Architects," which will shortly issue their report, in which will be found a more detailed description of the principles which underlie the production of successful work of this class, and to this report the writer would refer those interested; but the above may serve to emphasize the necessity of careful supervision, which, if exercised, will ensure that reinforced concrete will satisfy all that is claimed for it, and those who avail themselves of it may do so with the assurance that they have at their disposal a reliable addition to the materials which have stood them in good stead in the past.



A SURFACE FINISH FOR CONCRETE.

By HENRY H. QUIMBY, M. Am. Soc. C. E.

We have in previous issues dealt with several minor details relating to concrete work, such as safeguards against freezing, hair cracks in concrete, etc., as we constantly receive enquiries regarding small matters of this kind. In this instance we publish an article on the Surface Finish of Concrete, a matter of no small importance, and in giving a paper first presented in the United States, we do so as we consider the facts stated of equal value to the members of the technical professions and contractors in this country. We should add that we are indebted to the "Engineering News" of the United States for the very excellent illustrations.—ED.

THE concrete surfaces shown in the accompanying photographs are easily obtained. The process consists in completely flushing the face against the form, removing the form after the material has set but while it is still friable, and then immediately washing and rinsing the surface with water.

The washing removes the film of cement which has formed against the mould, and exposes the particles of sand and stone. The appearance then depends, of course, upon the character of the aggregate in the concrete and the uniformity of its distribution in the mixtures. As in well mixed concrete the cement merely fills the voids between the grains of sand, and the sand fills the voids between the pebbles or particles of crushed stone, the cement visible in this finished surface is so small a percentage that it has very little influence on the colour of the work.

A convenient means of securing a well flushed front, uniform in texture, is to make a fine concrete with the crushed stone or pebbles screened not to exceed, say, $\frac{3}{8}$-in., and apply it to the face form with a trowel just in advance of the body concrete, and ram the concrete into it or joggle the two mixtures together so as to ensure an intimate union. This fine concrete, or granolithic mixture as it is generally called, may be made of different coloured and different graded aggregates for different portions of a structure to compose a colour scheme.

The appearance may also be controlled somewhat by the extent of the washing, for if the work be done at the right time the washing brush can be plied to remove the mortar to a considerable depth between the stones, leaving the stone in a very decided relief and producing a rough, coarse texture which, by the way, seems to be the one most admired by the majority of observers.

The time to be allowed for setting before washing must be determined with regard to the nature of the cement used and to atmospheric conditions. Quick-setting cement and warm weather call for removal of form within eight or ten hours. The usual practice in summer, using almost any of the American Portland cements, is to remove the forms on the day following the deposit of the concrete. Of course this must not be done with the under or supporting portion of forms for arches and floors where the concrete is subject to stress, particularly in combination with reinforcement. Concrete that is sufficiently hard to sustain more compression than that due to the superimposed weight of a few of its own layers is too hard to wash.

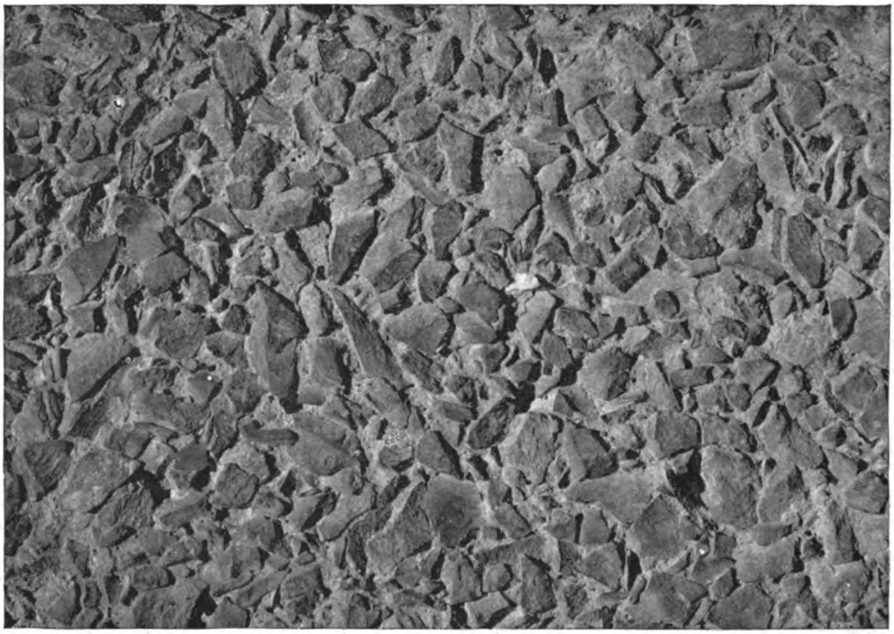


FIG. 1. CONCRETE COMPOSED OF 1 PART CEMENT, 2 PARTS YELLOW BANK SAND AND 3 PARTS $\frac{3}{8}$-IN. SCREENED STONE. ACTUAL SIZE.

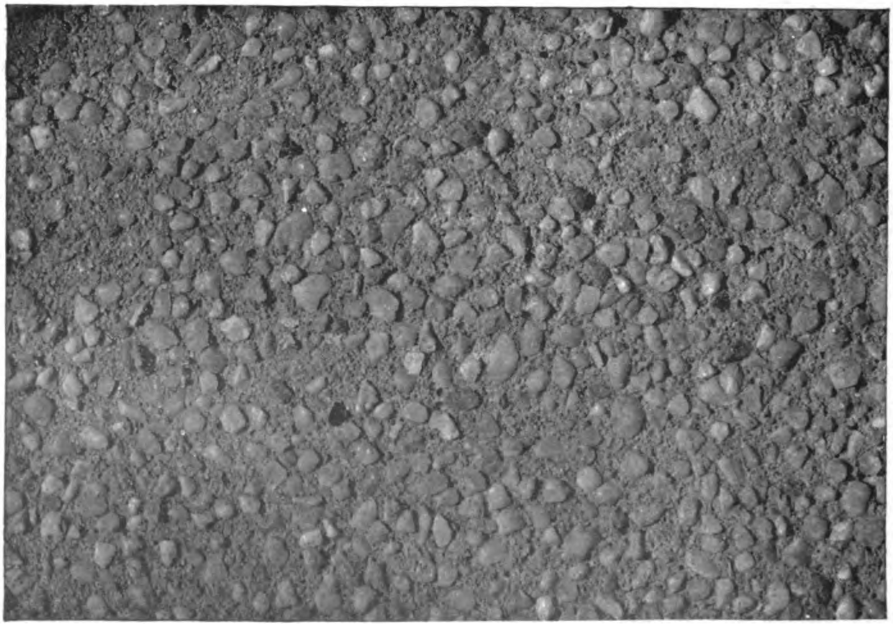


FIG. 2. PEBBLE AND SAND CONCRETE WITH SCRUBBED SURFACE COMPOSED OF 1 PART CEMENT, 2 PARTS BAR SAND AND 3 PARTS $\frac{3}{16}$-IN. WHITE PEBBLES. ACTUAL SIZE.

In cool weather when crystallisation proceeds more slowly, the washing is practicable two or even three days after laying, and in cold weather a whole week has been

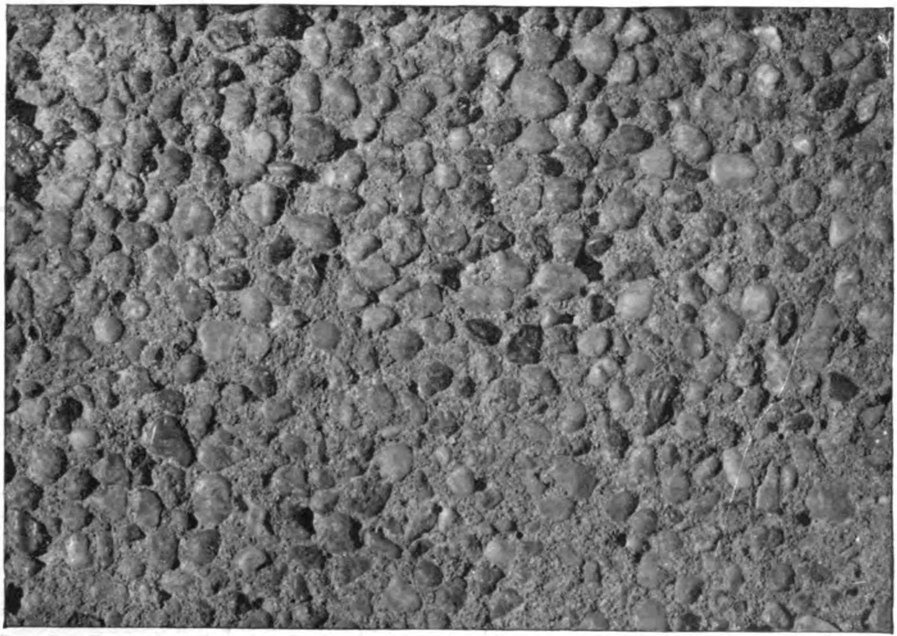


FIG. 3. SAND AND YELLOW PEBBLE CONCRETE COMPOSED OF 1 PART CEMENT, 2 PARTS BAR SAND AND 3 PARTS SCREENED YELLOW PEBBLES. ACTUAL SIZE.

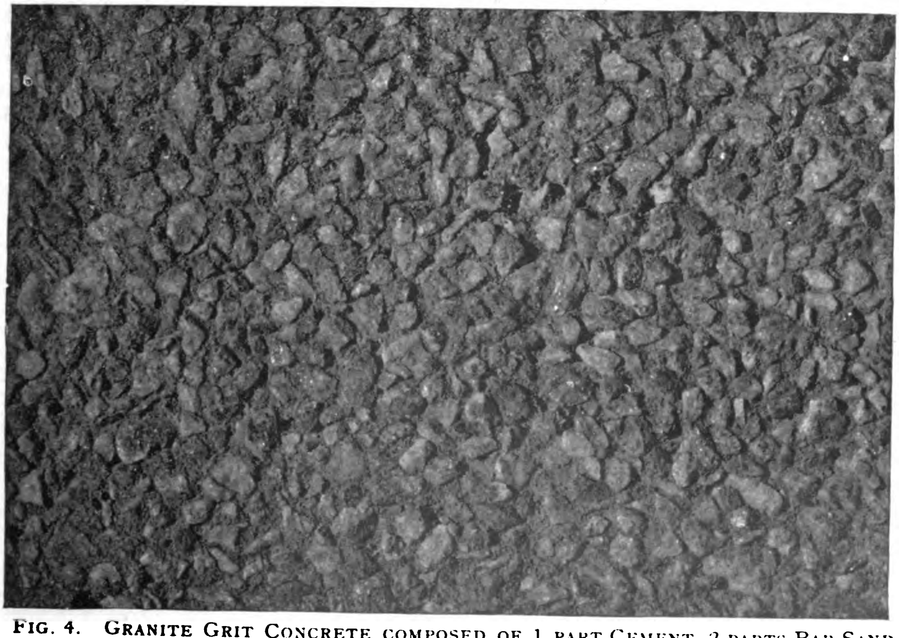


FIG. 4. GRANITE GRIT CONCRETE COMPOSED OF 1 PART CEMENT, 2 PARTS BAR SAND AND 3 PARTS ½-IN. GRANITE GRIT. ACTUAL SIZE.

found not too long to leave it in the forms when a slow-setting cement has been used. If it should happen that a face has been permitted to become too hard for washing with a brush, the film can be rubbed off with a small block of wood or sandstone with a copious flow of water, but it is, of course, laborious, and it cannot well be carried to the point of leaving the particles of aggregate in appreciable relief. The nearest approach to the washed surface is the effect produced by dressing with a sharp bush hammer and then washing with muriatic acid diluted one half. The acid should be well rinsed off.

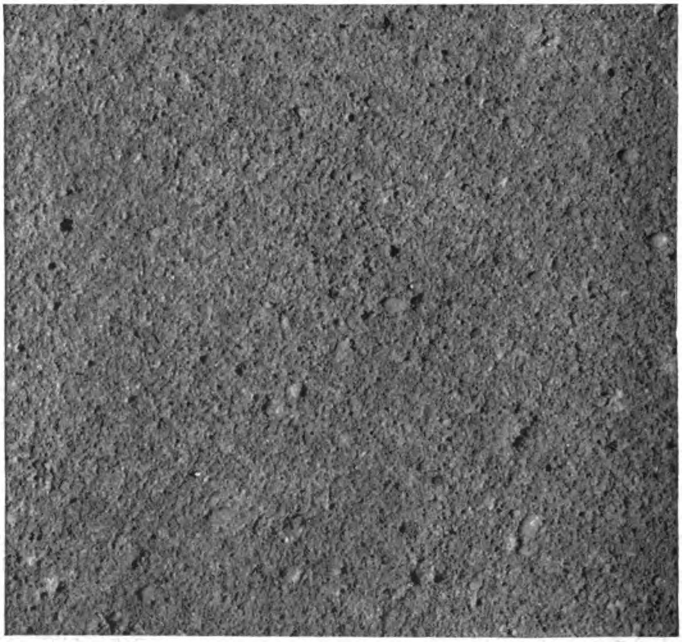


FIG. 5. CEMENT AND SAND MIXTURE COMPOSED OF 1 PART CEMENT AND 2 PARTS BAR SAND. ACTUAL SIZE.

If the height of the wall to be thus treated is too great to be completed in one day, face forms must be constructed to facilitate the removal of the planking without disturbing the studs or uprights. This is easily accomplished by setting the studs 8 in. to 12 in. away from the face line and supporting planks with cleats—say, 2 x 1 in.—tacked to the studs and the planks. This permits the lower planks to be removed and the washing done while the upper planks are in place and concrete being deposited. With the exercise of very watchful care on the part of the workmen and unremitting inspection, two different day's work can be joined so that after washing the joint will not be unsightly—even scarcely distinguishable, but such work is usually not obtainable throughout a structure, and it is found very easy to obtain thoroughly satisfactory joints by indenting horizontal grooves at regular intervals representing courses, and finishing each day's work at the apex of a groove. These indentations are made by means of triangular beads on the face forms. Usually the bead is the bevelled edge of a strip set between the face planks and lightly secured to the planks with partly driven toe nails, so that, if desired, a plank can be removed independently of the bead above it, the bead remaining to set the plank upon the next course. These grooves in the face of a wall improve the appearance by relieving the blankness of a large area. It is found practicable to prosecute the work with one course of planks where the capacity of the plant for one day is equal to only one course of concrete. In this way the same planks have been used for many different courses on four or more different structures.

The cost of washing depends upon the degree of hardness attained by the face.

If it be taken at the right time, three or four passages of an ordinary house scrubbing-brush, with a free flow of water from a hose or sponge, will be all that is required, and a labourer should wash, say 100 sq. ft. in an hour if the work is conveniently accessible. With a harder surface, such as it is likely to have within twenty-four hours in summer, scraping with a wire brush first will accelerate the washing, which may then require from two to five hours for 100 sq. ft. Bush hammering will cost probably from 5 to 10 cents per sq. ft., according to the quantity and the outfit.

This wash method of finishing has been in use for about three years, and the surfaces are quite as pleasing after the lapse of time as when fresh. As yet no hair or surface cracks have been found in any work that was washed, which is doubtless accounted for by the fact that the only material in which such cracks can develop is removed by the process.

A material advantage in the use of forms that are removable while the concrete is green is found in the opportunity for repairing blemishes. Incidental voids can be filled with the same material and bulges can be rubbed off because of its freshness without impairing the finish.

The accompanying illustrations are from photographs of specimens of various mixtures. The six cuts, representing different mixtures as labelled, show the actual size of the original.

It is important to direct the reader's attention to the fact in all of the concrete surfaces shown herewith the coarse aggregate projects in low relief. It may appear to one person in proper form while to another it may seem sunken or intaglio, as though the surface had formerly been incrusted with pebbles and sand, which had washed away. This is an optical illusion governed by the position of the light as it falls upon the page. If what are really crushed particles of stone or gravel in relief should appear as depressions, turn the picture upside down, or in proper position to get the true impression.

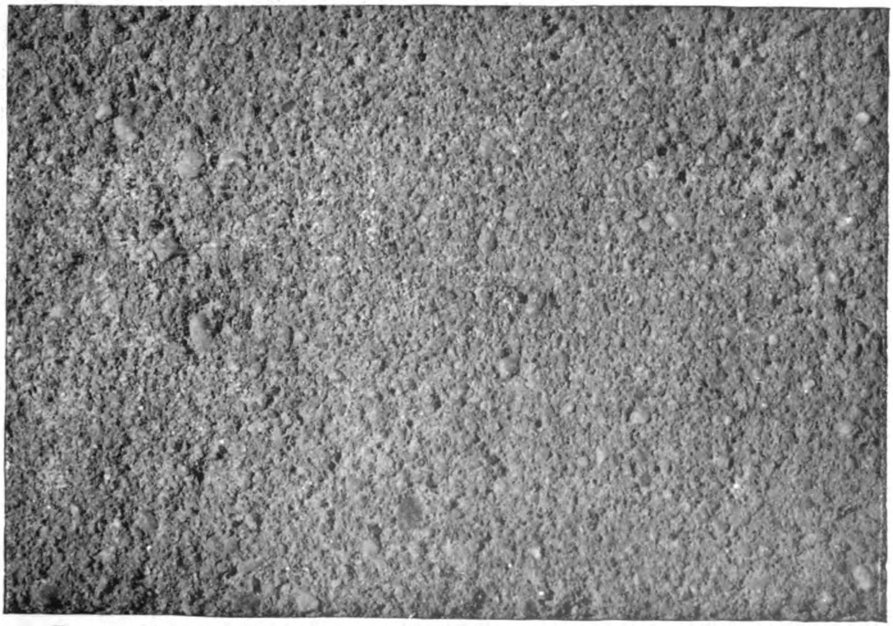
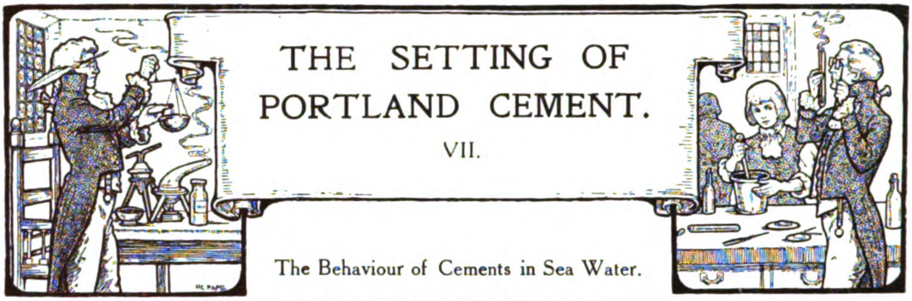


FIG. 6. YELLOW BAR SAND AND CEMENT COMPOSED OF 1 PART CEMENT AND 3 PARTS YELLOW BAR SAND. ACTUAL SIZE.



THE SETTING OF PORTLAND CEMENT.

VII.

The Behaviour of Cements in Sea Water.

By H. LE CHATELIER, Paris.

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier articles has encouraged us to extend our list of contributors on this subject to the leading authorities of other countries. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.

The contribution which we now publish is one by that eminent author, Monsieur H. Le Chatelier, of Paris, prepared originally for The International Testing Association at Brussels, and translated from the French by F. H. Leeds, of London.

This very valuable paper which, unfortunately, want of space only prevents our reprinting in extenso, throws some light on the vexed question of the use of gypsum in the manufacture of Portland Cement. Such addition made for the purpose of retarding the setting time of cement has been practised, more especially in Germany and other Foreign Countries, for some considerable time. The British Standard Specification admits of an addition of 2% of this material for that purpose. We understand, however, that this is not always effective, the cement on storage returning to its initial quick-setting condition, and this difficulty we note, has been a frequent subject for discussion at the Annual Berlin Congress of Cement Manufacturers. The difficulties of this question, and the objection so strongly taken by some engineers to the use of cement containing gypsum, seems to us to be met by a process referred to in a paper by Mr. D. B. Butler, A.M.Inst.C.E., F.C.S., published in our March issue, No. I., Volume II., page 24, by which the setting time of cement is regulated by a steaming process during manufacture, dispensing with the absolute necessity for the use of gypsum.

The author originally accepted the invitation of The International Association for Testing Materials with the idea of presenting a general review of the investigations that have been carried out upon the decomposition of hydraulic cements in sea water; but on attempting to collate the requisite documents, it was quickly discovered that but little precise information was available upon this important subject and therefore, in the present communication he has decided only to give a sketch of the laboratory experiments he has made himself during the past few years, a full report of which was recently published in the "Annales des Mines."†—ED.

MECHANICAL ACTIONS DUE TO CHEMICAL PHENOMENA.

If chemical reactions are the primary cause of the hardening of cement, it does not necessarily follow that all the reactions which take place amongst the products should have the same effect. On the contrary, there are cases where chemical reactions lead to the disintegration of cement. They may do this in two totally different ways, fraught with very unequal degrees of danger. The reactions may simply bring about a softening of the mass through a formation of compounds having a gelatinous consistency, the cement then losing its hardness and succumbing easily to mechanical agencies which attack it from the exterior—more particularly the action of waves—although its general appearance remains unchanged; or they may be accompanied by swelling and cracking until the material is wholly destroyed. For instance, when lime is slaked (an essentially chemical phenomenon), its hydration causes a swelling and cracking of the entire mass; but the hydration of lime is not the only chemical operation capable of producing similar fissures and swellings, for the action of sulphates upon hydraulic cements gives rise to the same phenomena of disintegration in a much less rapid fashion.

---

† "Observations préliminaires au Sujet de la Décompostion des Ciments à la Mer" (Preliminary Observations on the Decomposition of Cements in Sea Water). By H. Le Chatelier. Published by Mr. V. Ch. Dunod, 1904.

SWELLING CAUSED BY THE FORMATION OF CALCIUM SULPH-ALUMINATE.

By introducing important quantities of calcium sulphate into hydraulic cements, it is possible to bring about their disintegration at a more or less rapid speed; and, as a rule, destruction proceeds faster when the material is in the sea than when it lies under fresh water. The proportion of calcium sulphate a cement can bear without failing depends on its nature: cements poor in alumina though containing free lime, such as "ciments de grappier,"* and quick-setting cements containing much alumina but little lime, will tolerate considerable additions of sulphate, up to 10 per cent., without suffering appreciably.

The swelling observed in these experiments is the result of two opposite actions: 1, The expansion of the calcium sulph-aluminate; 2, the hardening produced by the hydration of the cementitious material; and the phenomena should therefore be rendered much more conspicuous if it were possible to eliminate the action which opposes the swelling.

At first sight it seems difficult to explain the development of the cracks which grow in cement when calcium sulphate is present; a brittle material like hard cement should apparently fall to pieces and should not on a priori grounds be able to swell and become distorted without complete rupture. The production of these cracks has been examined from two points (1) the Development of the Forces Involved, and (2) the Mechanism of the Deformation, and it would seem that the swelling observed in cements is merely an increase in the apparent volume, but not in the absolute volume of the substance—*i.e.*, whereas the total volume of solid matter diminishes the spaces between, the solid particles grow larger more rapidly, so that as a whole the mass exhibits an increase in total volume. The soluble crystals of calcium di-oxide or calcium sulpho-aluminate press one against the other, so to speak, and drive one another apart by pushing against the solid bodies with which they come in contact.

THE PHYSICAL PHENOMENA OF THE PENETRATION OF CEMENT BY SEA SALTS.

The mechanism of the processes whereby the saline matter of sea water penetrates into the interior of cement is of capital importance in studying the spread of decomposition.

POROSITY.

The first idea that presents itself is that sea water penetrates into cements by filtration under the influence of differences of pressure brought about by variations in the height of the sea, by the impact of waves, or by the emptying of dry docks. It is perfectly true that a passage of sea water occurs through masonry. This is easy to detect from the streams of water that issue from the walls when there is a difference of level in the liquid on the two sides. But such passage of water only takes place through flaws in the work, through cracks in the cement which joins the stones together. The penetration of water so caused has certainly a great effect upon the permanence of the structure, for it brings the decomposing action of the sea into the heart of the material; but it is quite independent of the nature and of the quality of the hydraulic substance employed. It is obvious that a circulation of liquid through a body of cement itself is almost impossible, for the speed of circulation depends not only upon the total section of the channels open to its passage, but also upon the dimensions of each of them. The state of subdivision (whether fine or coarse) of the precipitates formed by the action of sea water must cause the size of these channels to vary most irregularly, and so to oppose to the circulation of the liquid a resistance always great but very unequal in amount.

---

* "Ciment de grappier," a term for which there appears to be no English equivalent, is a by-product in the manufacture of hydraulic lime, and is prepared by grinding the residue left unattacked when the bulk of the material is slaked.

DIFFUSION.

The diffusion of salts does not meet with the same obstacles as the flow of liquids in porous bodies. Its speed depends solely upon the total free section of the passages, and not upon their individual size. It might be thought, therefore, that diffusion of salts should proceed in a much more regular manner than flow of liquids in bulk; and experiments have shown such to be the case. The method employed by the author to demonstrate this consists in immersing blocks of cement in saline solutions containing a body whose presence in the interior of the mass can be easily detected by appropriate chemical reagents. Among the substances tried, that which has given the best results is potassium ferrocyanide, for the dark blue precipitate produced when it comes into contact with a solution of ferric chloride in hydrochloric acid can be recognised with certainty. A 10 per cent. solution of sodium sulphide may also be used, for it has the property of striking a greenish-black colour wherever it penetrates in the briquette, without the intervention of any other metallic salt.

With the aid of this method it is interesting to study the behaviour of different kinds of hydraulic materials. Briquettes kept for three years under lime water were immersed for six months in the 10 per cent. solution of sodium sulphide. In these conditions most hydraulic limes and cements tested were penetrated to their centres—*i.e.*, to a distance of at least 10 mm. (the pieces being 20 mm. in diameter). A few, however, exhibited only very slight porosity. All the samples, with one or two exceptions shown in the following table, were re-ground before being gauged until they passed a sieve of 4,900 meshes. The proportion of water used was always large, generally about 50 per cent., in order to bring the condition of the cement briquettes in the matter of porosity into line with that of the hydraulic limes. In gauging the cements with so large a quantity of water, it was found necessary either to allow them to stand for a time before the operation was completed, or, more frequently, to start the setting process by heating the paste for a few minutes on the water-bath.

THREE YEARS OLD CEMENTS TREATED WITH SODIUM SULPHIDE.

No. of Sample	Nature of Hydraulic Material	Loss on ignition per 100 parts of residue (free and combined water)	Depth of penetration of the sulphide into 20 mm. cylinders	No. of Sample	Nature of Hydraulic Material	Loss on ignition per 100 parts of residue (free and combined water)	Depth of penetration of the sulphide into 20 mm. cylinders
1	Fat lime, 1 part; burnt clay, 0·5 part	175·7	total	11	Vitry slag cement	82·5	—
				12	Fat lime, 1 part; trass, 4 parts	88·4	5 mm.
2	English Portland cement ...	63·5	—	13	Cement of high hydraulic ratio	44·8	0 mm.
3	Fat lime, 1 part; burnt clay, 1 part	149·9	—	14	„ „ „ „	47·0	0 mm.
				15	Vassy cement, medium grade	91·5	total
4	Adulterated Portland cement, 1/2	59·9	—	16	Teil "Ciment de grappier." not ground	70·0	—
5	Adulterated Portland cement, 1/1	61·3	—	17	Teil hydraulic lime, well burnt	116·8	—
				18	Teil "Ciment de grappier" ...	72·2	—
6	Quick-setting Grenoble cement	101·2	—	19	Ditto + 1 part of burnt clay ...	127·41	—
7	Slow-setting „ „	83·6	—	20	Teil hydraulic lime	73·0	—
8	Boulogne Portland cement ...	56·75	—	21	Ditto + 1 part of calcined silica	144·0	—
9	Ditto + 1 part of burnt clay ...	111·3	—	22	Ditto + I part of burnt clay ...	95·0	1·5 mm.
10	Donjeux slag cement	76·1	—				

The first column of the table shows the loss in weight on ignition per 100 parts of residue, and represents very nearly the water used in gauging, except in the case of limes containing a noteworthy proportion of combined water. With the exception of No. 18, all the cements were ground before gauging, as mentioned above. Samples 15 and 16 were prepared specially at the Boulogne factory in order to see whether cements of high hydraulic ratio were better able to resist the decomposing action of sea water. The slurry had been made with 24·15 per cent. of clay. The proportion of water used in gauging was much smaller than in the other samples. These two cements were absolutely impermeable, whereas all the others were porous.

A mixture of Teil hydraulic lime with clay is shown to be almost entirely impermeable, while mixtures of Portland cement or "ciment de grappier" with the same quantity of clay are porous. But in this case the proportion of water was different—viz., 95 per cent. in the lime mixtures, of which about 8 per cent. already existed in the lime, as against 111 and 127 per cent. in the cement mixtures. The experiments quoted in the following table prove that mixtures of cement with clay also become non-porous when they are gauged with less water.

Nature of hydraulic material	Proportion of water	Penetration of sulphide
Lime and grey puzzuolana		8·0 mm.
Lime and yellow puzzuolana		3·0
Dèvres cement, well burnt, and grey puzzuolana	60 %	total
Ditto yellow ,,	56	0·5
Dèvres cement, under burnt, and grey ,	54	5·0
Ditto yellow ,,	60	0·8
Boulogne cement, excess of clay and grey ,,	51	total
Ditto yellow ,,	55	1·5
Boulogne cement, excess of lime and grey ,,	48	0·5
Ditto yellow ,,	55	3·0

Finally, a mixture of fat lime with trass was incompletely penetrated.

The above table shows the behaviour of mixtures of lime or cement with Italian puzzuolanas, a yellow and a grey specimen being used, for which the author is indebted to M. Rebuffat. Except when mixed with the fat lime, when they were employed in the natural condition, the puzzuolanas were ground like the cements. The cement mixtures were prepared with equal weights of material; the lime mixtures contained 4 parts of puzzuolana to 1 of lime. It will be seen that even when a considerable proportion of water is used—*i.e.*, 50 per cent.—hydraulic materials exist which yield absolutely impermeable mixtures.

It would seem that the greater or smaller permeability of hydraulic mortars to the penetration of saline matter by diffusion should be at least as important as differences in the chemical properties of the cements employed when the materials are to be exposed to sea water.

REMOVAL OF LIME BY DIFFUSION.

It has been recently pointed out by M. Maynard, Director of the "Laboratoire des Ponts et Chaussées" at La Rochelle, that chemical action is capable of materially altering the porosity of a cement and therefore its permeability to dissolved salts. He has observed that magnesia is never to be found in the interior of hydraulic cement, even when it is in a state of advanced decomposition, provided at least that disintegration is not complete; and yet the lime steadily disappears while the material regularly becomes more and more porous. The lime gradually diffuses from the interior towards the surface, meeting dissolved salts of magnesium which it precipitates.

The author has verified M. Maynard's statement by means of a qualitative process that gives very conspicuous results. Instead of immersing the samples in solutions of magnesium salts, the penetration of which can only be recognised by accurate analysis, he has used coloured salts of silver, mercury, copper, and cobalt. After remaining several months in such solutions, even cements of a relatively high porosity were only coloured to a depth of less than 0·1 mm.—*i.e.,* the penetration was practically *nil.* Here, of course, it is a question of penetration into a compact mass. When the cement cracks and disintegrates, as happens if sulphates of the above-mentioned metals (especially the sulphates of copper and cobalt which can be used in a concentrated form) are employed, the liquid enters by all the cracks, and their surfaces become stained; but on breaking the sample, it will be found devoid of colour at all places except the two walls of the fissures.

IMPERMEABLE COATINGS.

Although the chemical reactions that occur in cement are liable to increase the penetrability of the material, they are also, by a different procedure, capable of reducing its permeability to a considerable extent, and of closing all its pores. Two cases have to be distinguished according as solutions of chlorides or nitrates or solutions of sulphates are employed. In the former case, the superficial layer produced appears to become absolutely impervious; and, having always a high degree of adhesiveness, causes diffusion from the surface to the saline liquid to proceed very slowly, if indeed it continue at all. When sulphate solutions are used, the phenomena are totally different. The same film is formed; but, after a certain time, it becomes loose, giving rise to blisters, and falling away from the surface of the briquette. The swelling due to the presence of sulphuric acid leads to a complete destruction of the film, and thus allows the material to deteriorate progressively. Hence a fundamental difference must be drawn between solutions containing sulphates and such as do not contain them. In solutions free from sulphates—*e.g.,* that of magnesium chloride—all the experiments that have hitherto been carried out fail to show any decomposition whatever. The protection afforded by a skin of an insoluble metallic oxychloride or oxide appears to be absolute.

Inasmuch as sea water contains chlorides, sulphates, and bicarbonates, the different effects of these salts are produced simultaneously in an unequal fashion, according to the nature of the cements and manner in which they are employed. Very slight modifications in the experimental conditions either cause the film to be permanent and preservative, or prevent its persistence, and greatly accelerate the rapidity of destruction.

It may be interesting to examine the manner in in which lime disappears from a hydraulic cement by diffusion towards the exterior. The author has found a reagent —viz., mercuric chloride—that allows the progress of this diffusion to be studied with great accuracy. When a new fracture in a briquette is moistened with a saturated solution (10 per cent.) of mercuric chloride, and, after waiting 10 seconds, the place is washed with plenty of water, all parts of the briquette still containing free lime assume the yellow colour of mercuric oxide, all parts containing only silicates and aluminates of calcium take the reddish-brown colour of mercuric oxychloride, while the parts that have been completely converted into carbonate and decomposed remain colourless. On applying this test to briquettes which had been immersed for a year in solutions of sulphate and chloride of copper or cobalt, the author found the lime not to be completely removed at any point, for their broken surfaces turned reddish-brown except at the spot occupied by the extremely thin superficial layer of basic chlorides and sulphates. The free lime had vanished from a somewhat greater depth, but rarely from more than 1 mm. Thus it is manifest how powerful is the protective agency of the superficial film; for had the same briquettes been soaked even for a much shorter period of time in solutions of soluble salts like ferrocyanide or sodium sulphide, which are not precipitated by the cement, they would have been found to be impregnated with the saline matter to a depth of several centimetres.

MECHANISM OF THE DECOMPOSITION OF CEMENTS.

It follows from what has been said that the decomposition of cement is an effect of two successive actions: 1, The removal of lime by diffusion, which destroys the solidity of the material, and increases its porosity; 2, the swelling and disintegration of the weakened mass caused by the attack of calcium sulphate. The first phase of the phenomenon necessarily occurs in two very distinct periods. As long as cement contains free lime, the relatively great solubility of the latter enables it to diffuse rapidly; but when the lime has disappeared, and only silicates and aluminates remain, decomposition is still able to proceed in the same fashion because these bodies dissociate on coming into contact with water. Nevertheless, as the amount of lime liberated by dissociation is extremely minute, its elimination by diffusion is equally slow.

The mechanism of the second phase (decomposition by swelling) is more difficult to understand, for there is no penetration of foreign salts into the cement. It would seem that the cavities and cracks found in an old cement result solely from the stresses set up in the superficial skin by the process of expansion. As long as this skin is not firmly attached to the cement it may be detached without prejudice to the internal resisting power of the material; but when once, through the partial removal of the lime, the film has begun to be precipitated within the pores of the cement, and thus adheres firmly, the strains resulting from the swelling, which arises in course of time in the manner already indicated, succeed in producing cracks in the cement itself.

If it be admitted—and the author's experiments appear to establish it as a fact—that all the phenomena of decomposition which occur when cements are exposed to sea water (elimination of lime as well as swelling) depend on the action of a little impervious skin, possessing a greater or less power of expansion, and only a few tenths of a millimetre in thickness at the most, we can at once see why the behaviour of cement on a large scale is apt to appear capricious. Its degree of permanence is governed by the conditions that control the formation and destruction of this skin, which is in a state of perpetual transformation like a living creature, for lime is constantly being brought by diffusion to act upon its inner surface, while the magnesian salts of sea water attack it persistently on the outside. The magnesium compounds destroy the calcium sulph-aluminate which is then formed again either at the same spot or deeper in the body of the cement according to the irregularities in circulation of the lime and of the said magnesium salts.

CONCLUSION.

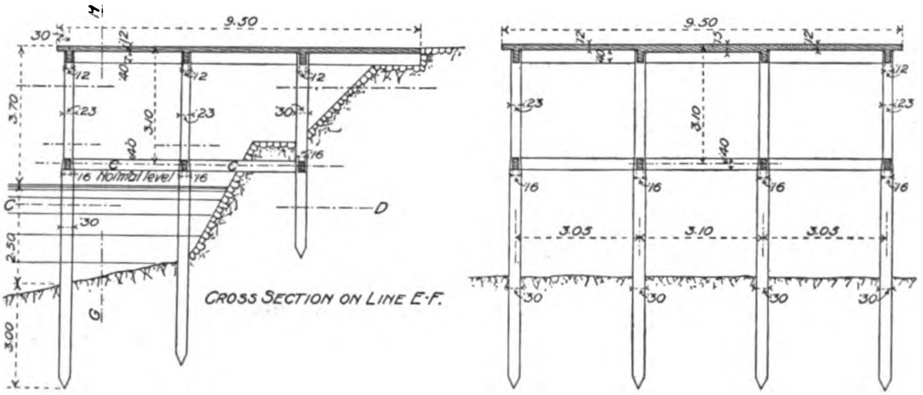
The foregoing observations show the following to be the most important conclusions that are to be drawn from a chemical point of view regarding the decomposition of hydraulic cements when exposed to sea water:—

1. All the active ingredients in cements—lime, aluminates, and silicates—are decomposed immediately they come into direct contact with the magnesium salts of sea water, yielding soluble chlorides and sulphates of calcium, and so bringing all the lime present into a state of solution.
2. When the calcium sulphate found in natural waters or formed by the interaction of magnesium sulphate and the calcium compounds of cement reacts with calcium aluminate, it produces a calcium sulph-aluminate whose crystallisation gives rise to swelling and cracking in the material. The action resembles that consequent upon the hydration of quicklime, but is much slower.
3. Penetration of marine salts takes place in two different ways: sea water penetrates *en masse* through all the flaws in the joints of the masonry and

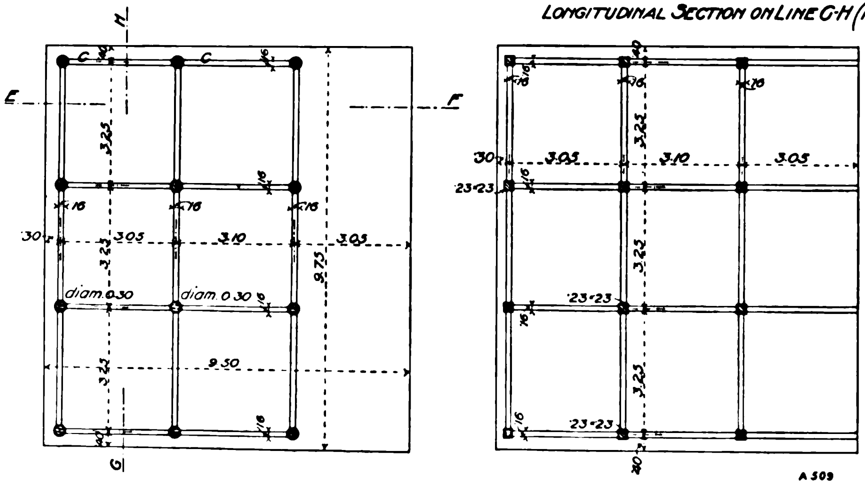
through the crevices in the stones and bricks themselves. Most of these flaws in workmanship are unavoidable. From the present aspect, the normal porosity of cement plays only a secondary part in the process.

Afterwards, when the cement is sound, circulation of, and attack by, sea water occurs almost exclusively by a process of diffusion, being the more rapid as the normal porosity of the cement is the greater.

4. All the phenomena of decomposition in sea water are at the mercy of a superficial film of extreme tenuity, whose impermeability tends to prevent, or rather to hinder, diffusive action, but whose expansion, caused by the formation of calcium sulphaluminate, promotes swelling of the material and cracks through which the salt water soon penetrates in quantity.



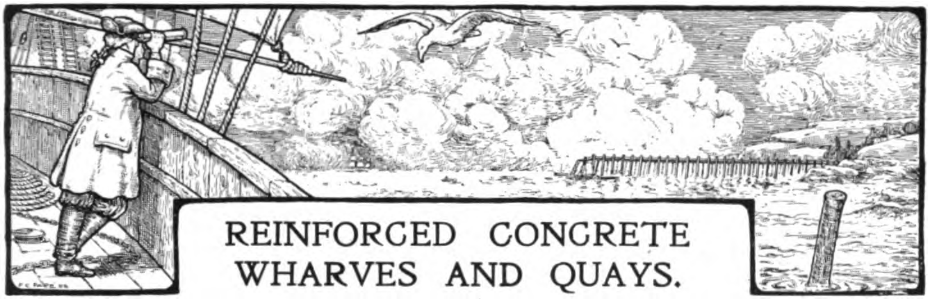
Longitudinal Section on Line G-H (Fig. 7.)



Plan on Line C-D (Fig. 7.)

Plan on Line A-B (Fig. 7.)

FIGS. 7 TO 10. WHARF AT DENNEMONT, NEAR MANTES.



REINFORCED CONCRETE WHARVES AND QUAYS.

BY W. NOBLE TWELVETREES, M.I.Mech.E.

We have previously published a series of articles dealing with reinforced concrete bridges by Mr. W. Noble Twelvetrees, and we are now presenting a further short series on the subject of Wharves and Quays, illustrating characteristic examples, both large and small, in which reinforced concrete has been used at home and abroad.—ED.

INTRODUCTION.

Within recent years the use of concrete in the construction of dock and quay walls and in the foundations of piers for harbour and bridge work has been steadily on the increase. The Admiralty Harbour, Dover, and the Keyham Extensions of the Devonport Dockyard are examples of undertakings in which enormous quantities of concrete have been employed, and where we may be perfectly certain the material would not have been considered for a moment if the least doubt existed with regard to its permanent durability.

In the present series of articles the writer proposes to deal briefly with applications of concrete to construction partly under water and partly above water, selecting for examples framed structures of reinforced concrete such as harbour and riverside wharves, quays, and kindred works.

It happens sometimes that the dock and harbour engineer finds a firm stratum of rock capable of supporting heavy foundations of mass concrete. More generally, however, alluvial soil is encountered, and is practically universal in rivers and estuaries. Therefore wharves, jetties, and landing stages have generally been built of timber, cast iron, or wrought iron, so as to impose the smallest possible weight upon strata of low bearing power. The inevitable decay of timber, and the corrosion of iron render these materials undesirable for structures partly above and partly below water level, to say nothing of the injury caused to timber by the attack of sea worms.

Reinforced concrete, when properly constituted, is free from these drawbacks, and at the present price of materials is less costly than timber. Consequently, it is being very largely used in riverside and harbour works in all parts of Great Britain and the Continent. So far as wharves and similar structures are concerned, reinforced concrete is almost invariably applied in the form of foundation piles extended upwards in the form of columns for the support of the decking beams and slab, and in many cases sheet piling is driven between the main piles for the purpose of banking up earth filled in behind the structure.

It is not necessary to discuss the general design of reinforced concrete piles, as that department has already been ably dealt with in a previous issue of this magazine.* But consideration will be given to any special forms of pile design occurring as details in the typical structures here selected as examples of wharf and quay construction.

---

* "Reinforced Concrete Piles in Tidal Waters," "Concrete and Constructional Engineering," Vol. I., No. 2.

QUAY AT LEVALLOIS-PERRET, PARIS.

The first example selected to illustrate reinforced concrete construction of the kind coming within the scope of the present series of articles is the quay built in accordance with the Coignet system of armoured concrete at the Levallois-Perret generating station of the Compagnie d'Eclairage Electrique du Secteur des Champs Elysées, Paris. *Fig.* 1 is a general view of the quay when nearly completed. At the left hand may be seen the timber staging used by the contractors; and at the right hand the timber coffer-dam built to permit the armoured concrete to be formed below water level.

The quay comprises three primary types of construction :—Timber pile foundations driven into the bed of the river, an armoured concrete retaining wall with a horizontal platform at the back for the purpose of counterbalancing part of the earth pressure, and the quay connected with and projecting beyond the retaining wall.

Fig. 2 is a front elevation of the quay, which contains five chambers open in front so as to serve the purpose of an intake for the elliptical pipe by which water is conveyed to the power house. The upper part of the quay contains five chambers, wherein are several electrically-driven pumps of small size, used for the supply of tanks and for starting the larger pumps installed in connection with the main water supply system of the works. The upper chambers are water-tight, and are lighted in the day-time by the windows indicated in the drawing. The length of the quay at the front is 17·50 metres, and at the back 21·11 metres, the width being 5 metres, including a cantilever projecting from the decking on the landward side.

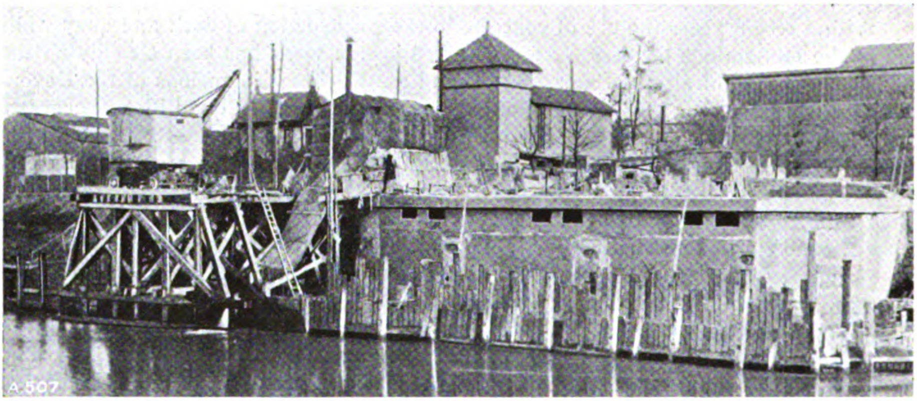
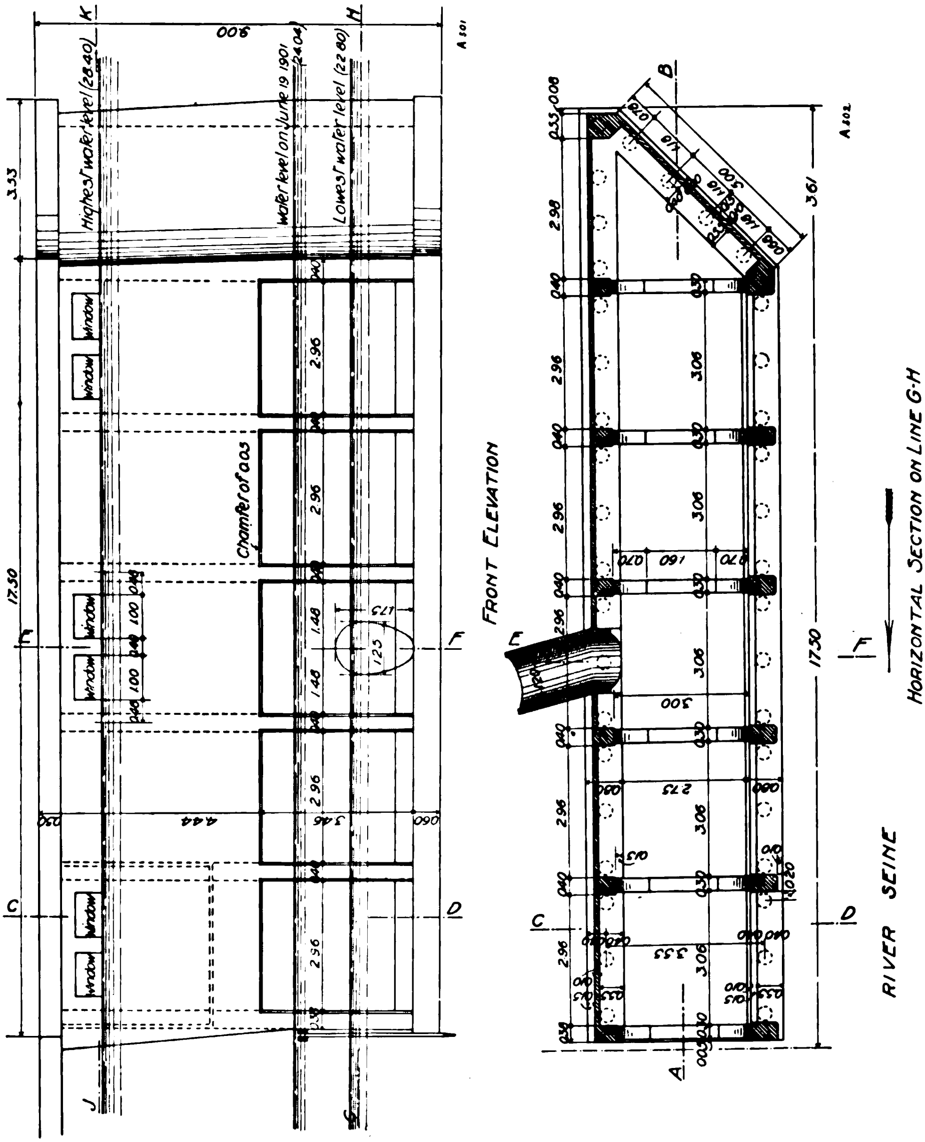


FIG. 1. GENERAL VIEW OF QUAY AT LEVALLOIS-PERRET, PARIS.

Fig. 3 is a horizontal section on the line GH (*Fig.* 2), showing the positions of the timber piles, the general arrangement of the main beams and columns, and part of the water supply pipe opening from the lower series of chambers.

Figs. 4 and 5 are transverse sections on the lines CD and EF (*Fig.* 3), where the method of construction is further illustrated.

The retaining wall is founded upon a rectangular footing, 80 centimetres wide by 60 centimetres deep, extending from end to end of the quay, and supported by nineteen timber piles, each of 30 centimetres diameter. It consists of a vertical slab of armoured concrete 10 centimetres thick, stiffened by horizontal ribs, 40 centimetres wide by 20 centimetres deep, and by vertical ribs, 40 centimetres square, spaced 3·36 metres apart centre to centre. These members may also be considered as columns in relation to the quay. The platform projecting for the distance of 2 metres at the back of the retaining wall is formed of two longitudinal beams, 20 centimetres wide by 40 centimetres deep, connected by transverse beams of similar dimensions, and by a continuous slab 10 centimetres thick. Above the platform are triangular counterforts connected with the retaining wall and the transverse beams of the platform.


Highest water level (28.40)
Water level on June 19 1901 (24.04)
Lowest water level (22.80)
Chamfer of 0.05
Window
Front Elevation
Horizontal Section on Line G-H
River Seine
A 101
A 102
17.50
3.33
9.00
3.61
A
B
C
D
E
F
G
H
J
K

FIGS. 2 AND 3. QUAY AT LEVALLOIS-PERRET, PARIS.

The idea of employing projecting spurs in this way is by no means a novelty to reinforced concrete designers, although it has recently been brought before the Society of Civil Engineers of France as a new feature in the construction of masonry retaining walls. The object of the projection is to utilise the weight of earth filled in behind the wall for the purpose of helping to prevent failure by overturning, and as the earth filling must be deposited in any event, the method is evidently conducive to economy.

But as a retaining wall may also fail by sliding along a horizontal joint, or by crushing at the toe, the platform method of construction does not provide completely for stability.

In the case of the Levallois-Perret quay sliding action is guarded against by embedding the heads of the piles in the foundation beams at the front and back of the quay. In this manner it was easy for the designers to provide a reasonable safeguard against failure by sliding. Security against the third method of failure is afforded by the intimate connection between the quay and the retaining wall, the two parts of the construction being so interconnected and so securely braced that they really constitute a single structure of such width as to render impossible any excessive strain. In addition to the counterforts, cantilever brackets are built out at the top of the retaining wall to carry an extension of the deck slab, as shown in *Figs.* 4 and 5.

Along the front and the slanting end of the quay there are nineteen 30-centimetre diameter timber piles, upon which is a footing 80 centimetres wide by 60 centimetres deep, and from this rise seven columns of the same dimensions as those at the back, and likewise spaced 3·36 metres apart centre to centre. Between the columns there are three horizontal ribs, 20 centimetres thick with the average width of 40 centimetres, all these members being connected by a 10-centimetre slab, forming the front wall of the quay above the five openings to the water intake chamber. The latter openings, 3 metres high by 2·96 metres wide, are fitted with cast iron gratings to prevent the admission of floating débris into the water supply pipe, the gratings being secured to the columns at each side of the horizontal rib at the top, and a cill, 20 centimetres thick by 46 centimetres high, built up from the footing.

Each pair of columns is connected by three transverse beams, measuring 30 centimetres by 60 centimetres, 30 centimetres by 50 centimetres, and 30 centimetres by 40 centimetres respectively, shaped so as to form two octagonal spaces, as may be seen in *Figs.* 4 and 5. The beams between the upper and lower chambers inside the quay are connected by a continuous floor slab 10 centimetres thick.

Along the slanting end of the quay the construction is of somewhat similar character, the chief difference being the absence of windows in the pump chamber, and of openings into the water intake.

Upon the decking, which is 10 centimetres thick between the main beams, rails are laid for the travelling crane used in unloading coals brought alongside in barges.

This quay was built from the designs of M. Benz by M. Edmond Coignet, of Paris, who prepared the actual working drawings in accordance with his well-known system.

All concrete used was mixed in the proportions of 3 parts of Portland cement, 5 parts of sand, and 10 parts of gravel.

WHARF AT DENNEMONT, NEAR MANTES.

As a second example of construction on the Coignet system, we take a small landing stage built on the banks of the Seine, at the works of MM. E. Candlot et Cie., the well-known cement manufacturers. *Fig.* 6 is a photographic view of the wharf, which, although not of imposing character, serves very well to illustrate the suitability of reinforced concrete for the most simple forms of wharf and quay construction.

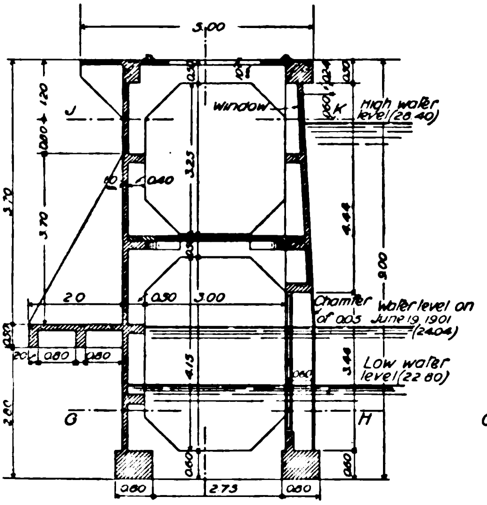
The total length of the wharf is 8·75 metres, and its width from front to back 9·50 metres, the decking being at the height of 3·70 metres above normal water level. The superstructure is carried on twelve armoured concrete piles of 30 centimetres diameter, driven to different depths in three rows, 3·05 metres and 3·10 metres apart, the four piles in each row being spaced 3·25 metres apart, centre to centre.

In the front row the piles are 5·80 metres long and driven 3·00 metres below the river bottom, those in the second row are 5·05 metres long, also driven 3·00 metres below the river bottom, and those in the third row are about 2·25 metres long, their heads being below the level of the ledge formed by the pitched facing of the river bank. (See *Fig.* 7).

For the support of the decking beams and slab, twelve columns are built up from the piles, and on the landward side of the last row of piles the decking is supported by the river bank.

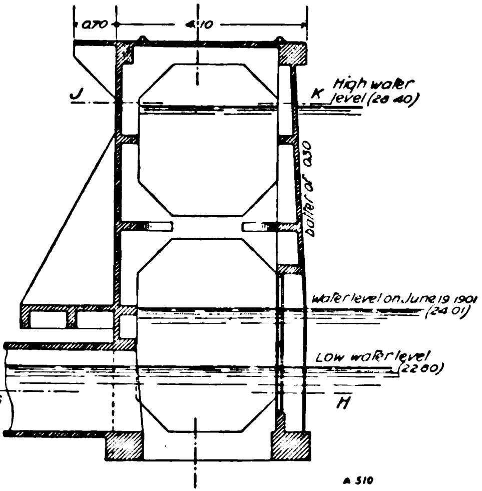
Fig. 8 is a longitudinal sectional showing the arrangement of the various members at the front of the wharf, and *Fig.* 9 is a plan viewed from below.

Having been driven to the predetermined depths, the piles were trimmed off to uniform level and connected by longtitudinal and transverse members, measuring 16 centimetres wide by 40 centimetres deep, forming six panels. Columns, 23 centimetres square, were then built up above the horizontal bracing in continuation of the piles, to the height of about 2·75 meteres, and were connected at the top by a second series of longitudinal and transverse beams, 12 centimetres wide by 40 centimetres deep, for the support of the decking slab, which is 12 centimetres beyond the centre of the beams in front, and 40 centimetres beyond the centre of the beams at each side.



TRANSVERSE SECTION ON LINE C-D

FIG. 4.



TRANSVERSE SECTION ON LINE E-F

FIG. 5.

QUAY AT LEVALLOIS-PERRET, PARIS.

At the same level the transverse beams are carried back to the river bank, forming supports for the remaining three panels of the decking, as illustrated in *Figs.* 7 and 10.

Having now indicated the main features of the landing stage, we will next give full details of the reinforcement as shown in *Fig.* 11, which is an exact reproduction of the working drawings, save in the respects that English is substituted for French in the lettering, and some of the smaller dimensions are omitted. We have thought it preferable to retain metric measurements, because all engineers are now accustomed to their use, and in many cases conversions are only approximately accurate unless carried to an inconvenient number of decimal places or expressed by the aid of equally inconvenient fractions.

Although described above as being round, the piles are not actually cylindrical, having two flat faces as represented in the plan and section in *Fig.* 12. The reinforcement consists of longitudinal steel bars and a spiral winding of steel wire. There are twelve bars of 12 millimetres diameter in each pile disposed at equal distances apart on the circumference of a circle with the diameter of 24 centimetres. Consequently, the bars are spaced about 6·3 centimetres apart centre to centre, and 3 centimetres from the outer surface of the concrete.

At the lower end of the pile a steel driving shoe is provided, and secured by four steel straps embedded in the concrete at the height of 35 centimetres above the point. All the longitudinal bars are brought together in the pointed portion of the pile, as represented in the drawing.

FIG .6.
GENERAL VIEW OF WHARF AT DENNEMONT, NEAR MANTES.

The spiral reinforcement consists of 6 millimetre diameter steel wire wound in coils 7 centimetres apart, measured vertically, and carried to about 1·50 metres from the head of the pile.

At the upper end of each pile the twelve bars constituting the longitudinal reinforcement are bent inwards, as shown in the part longitudinal section in *Fig.* 11.

The horizontal members of the bracing between the heads of the piles are all of the same dimensions. They are reinforced by four bars of 14 millimetres diameter, two near the top surface and two near the bottom surface of the concrete. It should be observed that these members are designed as struts, a fact which accounts for the adoption of one diameter for all the bars constituting the horizontal reinforcement. If intended to act as beams the bars near the upper surface would naturally be of smaller size than those below. In addition to the longitudinal reinforcement, vertical ties of 6 millimetre diameter steel wire are spaced at equal intervals of 10 centimetres along each strut.

To constitute a thoroughly rigid connection between the piles, columns, and horizontal bracing, the angles are filled up, as represented in sections AB and CD, *Fig.* 11, the rectangle so formed being reinforced by two bars of 16 millimetres diameter bent to the required form.

The part longitudinal section in *Fig.* 11 illustrates the construction of the columns rising to the deck beams, and further details are given in sections AB and CD. The columns, each 23 centimetres square, are reinforced by four vertical bars of 16 millimetres diameter, one placed near each corner, and the set of four wound spirally with 6 millimetre steel wire, the coils being 10 centimetres apart centre to centre.

The longitudinal bars of the columns are extended upwards, as shown in Fig 11, and being 13 centimetres apart centre to centre, there is sufficient room between them for insertion of the deck beams, so as to make a thoroughly sound joint. Each

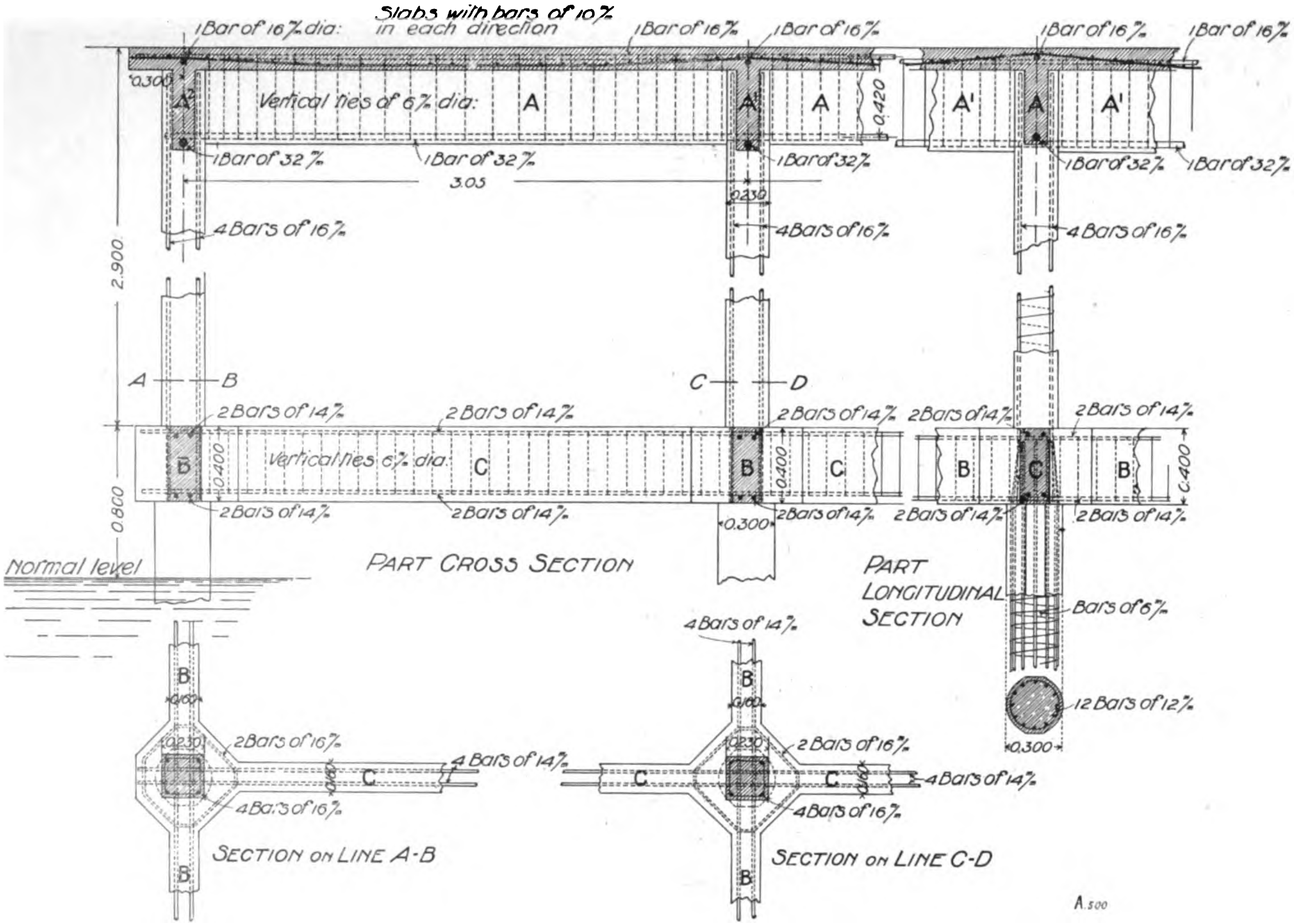
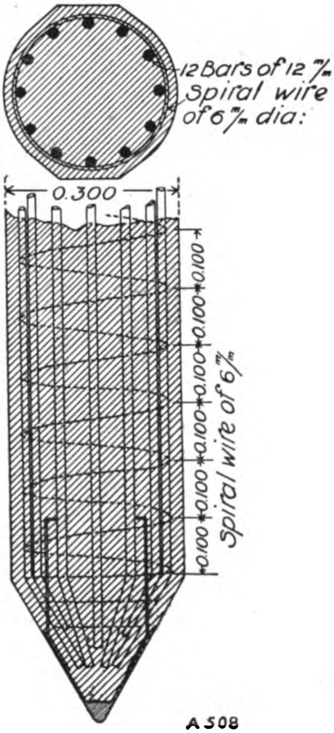


FIG. 11. DETAILS OF REINFORCEMENT. WHARF AT DENNEMONT, NEAR MANTES.



PLAN AND SECTION OF PILE
FIG. 12.

of the latter members is reinforced horizontally by one bar of 16 millimetres diameter in the compression area, and one 32-millimetre diameter bar in the tension area, the bars being connected by vertical ties formed of 6-millimetre wire, and spaced at progressively increasing distances apart in accordance with the diminution of shearing stresses and tension on diagonal planes towards the centre of the span. No special provision is made in the deck beams for continuous-girder action, which necessarily arises in construction of the kind now in question, whether or not it be intended by the designer. In the deck slab, however, the reinforcement is disposed suitably for continuous-girder action, the bars, which pass in two directions, being curved downwards from each support.

Each panel of the decking is reinforced by eight bars of 10 millimetres diameter in a direction parallel with the front of the wharf, and eight bars of the same size at right angles to those of the first series, all the bars being curved upwards, so as to pass over the tension reinforcement in the main beams. Those bars which are near the front and side columns are prolonged for the reinforcement of the cantilever projections of the slab.

The landing stage was built in 1906 from the designs of M. E. Candlot, the contractor being M. Edmond Coignet, of Paris.

Fatigue of Concrete and Reinforced Concrete.

By CHARLES F. MARSH, M.Inst. C.E., M. Am. Soc. C.E.

While the Fatigue of metals has been frequently dealt with by investigators of eminence, comparatively little research work has been undertaken in the Fatigue of Concrete and reinforced concrete. We thus welcome the investigations undertaken by Professor Van Ornum, and dealt with in the following pages by Mr. Charles F. Marsh, and to those to whom the technical details of the enquiry are not of sufficient interest to follow in full, we would refer to the final paragraphs, in which valuable conclusions are presented, conclusions which it would be well to take to heart.—ED.

PROFESSOR J. L. VAN ORNUM in Vol. XXXII., No. 10, of the Proceedings of the American Society of Civil Engineers (December, 1906), describes some tests he has recently carried out on the fatigue of plain concrete in compression and reinforced concrete under flexure. A great number of tests were made (about 600 in all), partly by reason of the variability in strength of individual test specimens, which must occur with such a material as concrete, necessitating a large number of tests to obtain a fair average, and partly in consequence of the nature of the enquiry.

In the first place it was essential to obtain a correct value for the resistance of the concrete under one loading so that proper estimate could be obtained for the several percentages of such ultimate loading to be employed in the repetition tests for ascertaining the effect of repeated loads.

It is hardly necessary to point out that if the average load required to crush a specimen under a single loading was too high or too low, the several percentages of the full load taken for the fatigue tests would also be too high or too low, and consequently the results obtained would be very misleading.

In Professor Van Ornum's tests such inaccuracies have been avoided by making a considerable number of tests, thereby eliminating the effects of abnormally high or low resistances.

The concrete used for the test specimens was in the proportions of 1 cement, 3 sand and 5 of stone. The cement was of excellent quality, the sand was water-worn, rather fine, and varying considerably in important characteristics with different consignments. The proportions of the various sizes of grains were as follows :—

Retained on sieve with 10 meshes per lineal inch, 5 to 10%.
Passing sieve with 10 meshes and retained on sieve with 20 meshes per lineal inch, 10 to 15%.
" " 20 " " " 30 " " 15 to 27%.
" " 30 " " " 40 " " 20 to 25%.
Passing sieve with 40 meshes per lineal inch, 23 to 50%."

The voids in the selected sizes of sand varied from about 38 to 30 per cent., and for unscreened sand as delivered from 33 to 26 per cent.

The weight of the sand was about 99 to 110 lb. per cub. ft. when dry and moderately shaken.

The stone was broken limestone crushed to pass a 1½-in. screen—about one-half was larger than 1 in. and about one-tenth was less than ½ in. in size, and its voids varied from 42 to 48 per cent.

The percentage of voids in the 3 parts of sand and 5 parts of broken stone was from 16 to 19 per cent.

The unscreened materials were used so as to more nearly approximate the conditions which would obtain in practical construction.

The compression specimens were left in the moulds in air for one day and the reinforced concrete beams for two days, the moulds were then removed and the specimens placed in water for two weeks, and were then stored in air protected from draughts until tested.

The number of loadings for the entire series of tests amounted to considerably more than 500,000, and consequently an automatic, electrically-controlled apparatus was constructed to apply and remove the loads, the tests being continued night and day without intermission, while a registering device gave the number of repetitions.

COMPRESSION TESTS.

Series of tests on specimens under compression were made at ages of one month and one year, the prisms tested being about 5 in. by 5 in. by 12 in. high, the corners being rounded. The net section averaged 23·6 sq. in.

Proper precautions were taken to obtain an even bearing at the ends.

It was necessary to apply an initial load of 500 lb. to prevent the specimen falling out of the testing machine on removal of the load, and this was the minimum pressure on all specimens. The rate of application of the loadings depended upon the percentage of the applied load to the ultimate resistance, and varied from 4 to 8 per minute. Generally two blocks from each mixing of concrete were tested to failure to obtain the 100 per cent. load. If these tests gave very different values, or if the repetition tests of the same mixing were so erratic as to indicate a probable error in the 100 per cent. load, other specimens were crushed, until an apparently average 100 per cent. value was secured. A certain percentage of this ultimate load was then taken as the repetition loading for the fatigue tests.

Tables 1 and 2 give the results of the one month ultimate and repetition tests, the average ultimate resistance at this age being 1,200 lb. per sq. in.

Tables 3 and 4 give in a similar manner the results of the one year tests, the average ultimate resistance at this age being 1,580 lb. per sq. in.

Note.—It must be borne in mind that the proportions for the concrete were 1 : 3 : 5, whereas the weakest mixture usually employed for reinforced concrete is 1 : 2 : 4, and in consequence the crushing strengths are somewhat lower than those obtained for the concrete used in reinforced structures.

TABLE 1.—One Month Compression Tests. 100% Loads.

30 000	32 610	23 500	31 650	37 280	27 230	22 740	28 100	37 000	30 020
20 000	30 100	30 500	32 230	26 780	23 250	23 210	30 200	25 400	37 060
31 140	31 280	30 120	33 200	21 020	34 400	30 780	32 500	27 800	23 090
25 820	23 000	26 000	26 400	26 500	33 800	30 100	29 750	26 600	23 480
25 650	25 000	24 000	27 610	19 800	23 330	27 400	28 000	36 000	30 870
25 130	23 020	36 560	35 480	22 850	32 930	35 600	29 700	21 500	25 400
27 270	23 100	26 000	30 840	24 780	36 860	26 200	31 570	24 000	23 430
27 400	20 970	25 800	31 220	34 150	30 040	28 000	34 160	19 800	29 340
28 450	26 240	31 200	29 950	27 660	35 240	24 800	26 720	32 150	32 040
27 640	23 200	25 800	24 200	30 810	31 360	33 000	28 410	25 700	30 500
30 900	22 540	26 700	28 190	30 200	25 380	32 900	35 760	25 220	25 620
19 280	26 000	28 040	35 160	26 800	26 800	32 110	33 810	32 290	29 050
31 090	37 500	25 720	31 880	26 800	24 640	24 600			22 940

Average of 128 = 28 350 lb.

TABLE 2.—REPETITION TESTS.

95%	90%	85%	80%	75%
6	102	131	123	826
92	51	20	85	101
4	2	25	145	233
3	79	1	57	384
3	151	750	109	1 119
16	3	206	79	416
31	14	26	1 527	168
150	29	198	28	
13	91	91	128	
54	1		656	
16	418		3	
3	206		37	
175	226		124	
8	35		22	
9	77			
3				
Av. of 16 = 37	Av. of 15 = 99	Av. of 9 = 161	Av. of 14 = 223	Av. of 7 = 464

70%	65%	60%	55%	50%
135	2 227	2 016	443	10 711
332	185	665	5 025	21 070
4 405	246	596	1 113	19 800
280	207	1 431	165	
350	13	994	431	
324	32	356	15 629	
1 020	1 881	10 711	173	
1 345	4 005	9 210	2 064	
359	62	7 200	52 440	
	27			
	185			
	5 304			
	510			
	9 957			
	5 525			
	247			
	1 875			
Av. of 9 = 950	Av. of 17 = 1 911	Av. of 9 = 3 687	Av. of 9 = 8 609	Av. of 3 = 17 194

The repetition results given in Tables 2 and 4 cannot be considered as giving the precise average, as the range of values is considerable, owing to the causes already mentioned, still it may fairly be assumed that the combined results closely approximate the true law of the fatigue of concrete.

TABLE 3.—ONE YEAR COMPRESSION TESTS.
100% LOADS.

34 260	33 400	33 750	36 680	44 900
46 670	26 440	29 150	44 840	38 650
48 400	45 200	44 100	48 160	49 600
36 200	26 800	30 200	36 540	35 570
39 200	39 860	35 330	36 000	32 720
43 040	31 840	38 700	35 690	32 830
32 000	35 150	35 660	42 500	37 740
30 200	37 500	33 900	44 950	42 700
34 400	37 600	3 600	27 100	39 000
43 350	34 150	27 350	37 000	32 000
33 800	38 600	37 850	40 490	45 960
39 240	41 400	31 000	37 700	44 400
				35 600

Average of 61 = 37 370 lb.

TABLE 4.—REPETITION TESTS.

95%	90%	85%	80%
3	11	79	175
2	23	14	1 951
3	115	179	192
27	2	137	15
2	9	94	265
4	10	38	1
98	94	811	57
4	19	194	328
3	3	8	600
31	1	345	40
	12	139	
		90	
		3	
		713	
		47	
Av. of 10 = 18	Av. of 11 = 27	Av. of 15 = 193	Av. of 10 = 362

75%	70%	65%	60%	55%
971	2 145	1 168	7 867	2 480
1 138	3 279	2 378	450	83 159
183	332	1 600	10 673	4 237
110	275	2 067	1 360	40 302
542	16	3 731	3 579	
	1 130			
Av. of 5 = 589	Av. of 6 = 1 230	Av. of 5 = 2 189	Av. of 5 = 4 786	Av. of 4 = 32 545

A further 50 tests were made to determine whether the rate of application of the load had any noticeable effect on the law of fatigue—in these experiments the rate was never greater than 4 per hour and averaged 1 loading in about 5 hours; about three-quarters of these 50 tests were on compression specimens and one-quarter on beams.

The percentage of ultimate load varied between 85 and 92 per cent. and averaged 89 per cent.; the average number of repetitions to produce failure was 35 for the compression specimens and 62 for the beams.

No systematic difference in the relation between the percentage of the ultimate load and the number of repetitions was found on comparing these values with those in Tables 2 and 4 above and Tables 6 and 8 which follow on inspecting the figures for the respective tests, and certainly there was no considerable increase in the number of repetitions necessary to cause failure even when the fastest rate was reduced one hundred times. Professor Van Ornum, however, is of the opinion that a noticeable effect is produced when the rate of loading is greater than 10 per minute, which increases rapidly as the rate of loading is increased, while with a rate of loading less than 8 or 10 per minute little or no effect is produced by varying the rate of repetition.

REINFORCED CONCRETE BEAMS.

The beams tested were 6 ft. between the supports, 4 in. wide, and 6 in. deep. The reinforcement consisted of two plain ½-in. square steel bars, with their centres 1 in. above the bottom of the beam and 1 in. from the sides, the steel being rather more than 2 per cent. of the area of the concrete above its axis. The elastic limit of the steel was 29,000, and the ultimate resistance 59,000 lb. per sq. in. The large percentage of steel was used in order that the concrete should fail in compression.

The mixture of the concrete and the treatment of the specimens before testing has been already describd.

The rate of application of the load varied with the percentage of the ultimate resistance, and was between 2 and 4 per minute.

Tables 5 and 6 give the details of the one month tests, and Tables 7 and 8 those for greater ages. The tests at 6 and 12 months were combined, partly because the results at these two ages contain no systematic differences, and partly because the number of tests at the age of 1 year were too few for independent use.

TABLE 5.—ONE MONTH TESTS, REINFORCED CONCRETE BEAMS. 100% LOAD.

2 800	2 950	2 050	2 440	2 400	3 530	3 050	2 080	2 200	3 820
2 860	3 250	2 930	2 610	3 460	3 760	3 650	3 400	3 060	2 720
3 760	3 940	2 470	2 460	2 920	3 500	3 150	2 980	2 630	2 060
2 860	2 680	2 360	2 920	2 600	2 400				

Average of 36 = 2 909 lb.

TABLE 6.—REPETITION TESTS.

90 99%		80-89%		70–79%		60–69%		50–59%		90–99%		80 89%		70–79%		60-69%		50 59%	
%	Repetitions.	%	Repetitions.	%	Repetitions.	%	Repetitions.	%	Repetitions.	%	Repetitions.	%	Repetitions.	%	Pepetitions.	%	Repetitions.	%	Repetitions.
91	36	80	388	75	92	63	6 476	53	4 170			85	7	70	79	68	165	59	5 400
91	9	85	96	70	480	64	570	58	2 205			85	75	70	155	60	162	59	7 670
91	1	80	56	74	3 880	60	1 384	59	5 300			80	227	77	516	65	2 507	53	14 080
94	31	85	1	72	55	66	59	56	3 655			86	334	77	1 600	62	34		
92	1	80	256	70	13	64	120	53	2 538			86	74	77	39	69	2 016		
		80	9	75	14	66	1 630	56	3 560			80	1	70	24	67	1 622		
		80	585	70	86	64	21	59	2 227					74	1 310				
		80	23	75	760	68	6 316	50	1 527										
Av. of 5 = 92% · 16 repetitions.		Av. of 14 = 83% ; 152 repetitions.		Av. of 15 = 73% ; 640 repetitions.		Av. of 14 = 65% ; 1 649 repetitions.		Av. of 11 = 56% ; 4 757 repetitions.		Av. of 5 = 92% ; 16 repetitions.		Av. of 14 = 83% ; 152 repetitions.		Av. of 15 = 73% ; 640 repetitions.		Av. of 14 = 65% ; 1 649 repetitions.		Av. of 11 = 56% ; 4 757 repetitions.	

TABLE 7.—SIX-MONTH AND TWELVE-MONTH TESTS, REINFORCED CONCRETE BEAMS. 100% LOADS.

5 100	3 890	3 400	5 130
3 300	3 540	4 750	4 640
3 020	4 230	5 140	4 940
4 080	3 440	5 000	5 210
3 860	3 610	4 350	5 170
4 660	4 060	4 970	3 180
3 090	3 600	* 4 100	*4 700
*4 120	*4 850	* 4 100	*4 000
Average of 32 = 4 226 lb.			

* Results of tests at age of 12 months: all others made at age of 6 months.

TABLE 8.—REPETITION TESTS.

80-89%		70-79%		60 69%		50 59%	
%	Repetitions.	%	Repetitions.	%	Repetitions.	%	Repetitions.
81	14	75	709	60	1 777	56	4 117
81	* 18	72	492	67	2 970	55	*4 190
80	*140	70	1 643	65	2 735	59	*4 915
80	* 2	78	27	68	9		
89	* 9	75	312	68	2 608		
		79	113				
		70	317				
		74	* 297				
		78	*1 634				
		70	* 507				
Av. of 5= 82%; 37 repetitions.		Av. of 10= 74%; 605 repetitions.		Av. of 5= 66%; 1 948 repetitions.		Av. of 3= 57%; 4 407 repetitions.	

* Results of tests at age of 12 months; all others made at age of 6 months.

From this series of tests Professor Van Ornum considers that the actual law of fatigue is fundamentally independent of variations of conditions, and that the number of repetitions to cause failure depend essentially upon the percentage which the test load bears to the ultimate resistance, the variations between the several values, and the mean for each series of tests being well within the limits of accidental errors in such a material as concrete.

Fig. I. represents the summarized law of fatigue being plotted from the results in Tables 5, 6, 7 and 8.

This curve is of considerable interest, and for the number of tests carried out may be taken as fairly approximating the law of fatigue with so variable a material as concrete.

It will be noticed that the average result of the three compression tests at 1 month at 50 per cent. load is somewhat low, but Professor Van Ornum considers that this is due to accidental causes, which are not shown since the number of repetitions necessary with such a low percentage of the ultimate resistance made it impossible to test a sufficient number of specimens to nullify accidental results, and also because the 1 year tests at 55 per cent. load give an average nearly double that of the 50 per cent. load 1 month specimens, although the two specimens at this percentage which are entered as failing after more than 40,000 repetitions were in reality crushed at higher loads after this number of repetitions, as they showed no

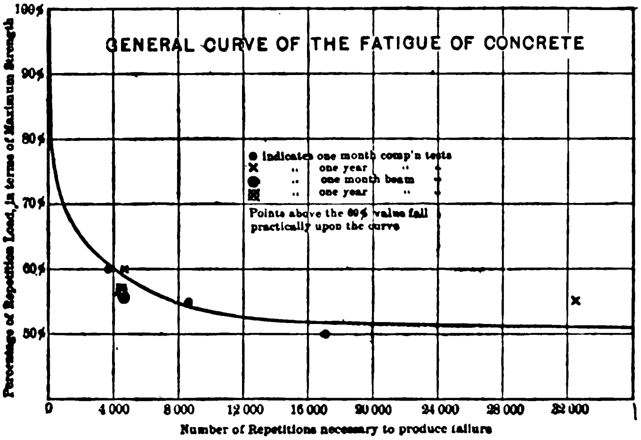


FIG. 1.

indications of weakness. Other of the specimens were similarly treated after a considerable number of repetitions were reached. The "52,440" specimen in the 55 per cent. column of Table 2 was finally crushed under a load 55 per cent. greater than its repetition loading; the "40,302" specimen in the 55 per cent. column of Table 4 under a final load 87 per cent. above its repetition loading, and the "83,159" in the same column was broken finally under a load 65 per cent. greater than the average ultimate resistance of the concrete.

Fig. 1 shows that the curve indicating the law of fatigue becomes a straight line at or about 50 per cent. load, from which it is fair to assume that under a stress less than half the ultimate resistance of concrete there is practically no effect due to vibrations applied at a much higher rate than that likely to obtain in actual practice.

Figs. 2, 3 and 4 show the typical failures of the beams, the centre of the beam being shown by the dark spot.

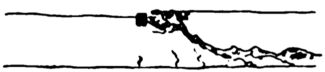


FIG 2

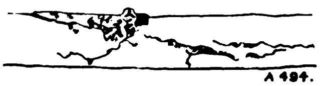


FIG 3

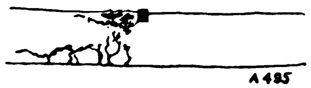


FIG 4

The failure commenced by tension cracks, followed usually, but not always, by inclined cracks, the final failure being always due to the compression of the concrete at the top of the beam.

Fig. 2 indicates the final failure of the greater number of the beams. The diagonal cracks usually commenced below the centre of depth of the beam and developed gradually downwards towards the nearer support, approaching the horizontal as they neared the lower surface, until they became absolutely horizontal at the plane of the upper side of the horizontal bars. Sometimes, however, the diagonal cracks crossed the bars and joined the tension cracks already developed, in other cases the tension cracks developed upwards, sloping towards the centre of the beam instead of the diagonal cracks extending downwards. The diagonal cracks, besides developing downwards, extended upwards at the same time until the compression surface was reached, when the final failure took place by crushing of the concrete.

Occasionally the prism of concrete on the compression surface broke completely away from the rest of the beam, being typical of what may be called a shearing compression failure; in such cases the diagonal crack when reaching the top of the reinforcing bars became horizontal and continued so to the very end of the beam. This form of failure is shown in *Fig.* 3.

Fig. 4 shows another form of failure, where the diagonal cracks were not produced and the concrete was crushed at the top of the beam, after tensile cracks had developed sufficiently.

In all cases where the diagonal cracks formed a marked factor in the fatigue of the beam, a gradual destruction of the bond between the concrete and steel appears to have influenced the behaviour considerably. In general this destruction of the "adhesion" commenced near the centre of the span and progressed toward, but without reaching, the supports. The slipping of the bars was found, by breaking open the beams both before and after the appearance of diagonal cracks, to occur after the development of diagonal cracks, except in some few instances when it occurred prior to their formation. The slipping of the bars was apparent from various evidences. On breaking open the beams, it was found that the adherence was entirely lacking throughout the central portion, whereas there was a strong tendency for the concrete to adhere to the steel at the ends. Where the bond remained effective the surface of the steel when exposed was dull, while it had a polished, glassy appearance where the bond had been broken. Frequently the surface of the concrete towards the centre of the span, where it had enclosed the bars, showed striation marks, caused by small projections on the steel etching the smooth surface of the concrete where the bars had been drawn through. These striation marks were very rarely found when the failure was essentially that of compression of the concrete, but were invariably present when diagonal cracks were prominently developed. Among other evidences of the slipping of the bars in the concrete, Professor Van Ornum frequently noticed a succession of distinct reports in the interior of the beam when the load was being applied, followed by a continuous, low, rasping sound as the beam was relieved of the load. No exterior deterioration of the beam was discovered when this phenomenon was produced. It appeared that any rust on the metal, although completely absorbed by the concrete, lessened the adhesive power materially, the concrete often lacking adhesion opposite rust discolourations, while the bond was perfectly secure on each side. When the adhesion was destroyed through the central part of the span the destruction always terminated with a discoloured section, apparently indicating that the increased adhesive resistance to the cleaner portion of the steel beyond the rust spot stopped the breaking of the bond.

Professor Van Ornum also noticed that excess of water used in the mixing of the concrete lessened the adhesive power of the concrete in a marked degree. He points out that while a moderately wet moisture is desirable, there is considerable danger in an excessively wet concrete such as is used very frequently at the present time, and sounds a warning note against sloppy mixtures. M. Feret and others have found that up to a certain point the adhesive resistance increases with the addition of water, and that a dry concrete is not to be recommended for obtaining the best adhesive results, but the reaction against dry mixtures is frequently carried too far, and it is well that emphasis should be laid on the danger which may be incurred by the use of excessively wet concretes.

ELASTIC BEHAVIOUR UNDER REPEATED LOADINGS.

About 100 beams and prisms were tested for their elastic behaviour, upwards of 10,000 observations being taken with this object. For comparative purposes the values of the modulus of elasticity at different stages of the fatigue were obtained by dividing the total unit stress at the repetition load by the total unit strain occurring between the zero and the repetition load, regardless of the intermediate variations in the slope of the stress strain curve.

PRISMS UNDER COMPRESSION.

The results thus obtained from various prisms under compression are shown in the upper part of *Fig.* 5 for specimens where the percentage of the ultimate load used for the repetition loading was sufficient to produce failure, and in the upper part of *Fig.* 6, where the percentage of the ultimate load was insufficient to crush the piece by repetition.

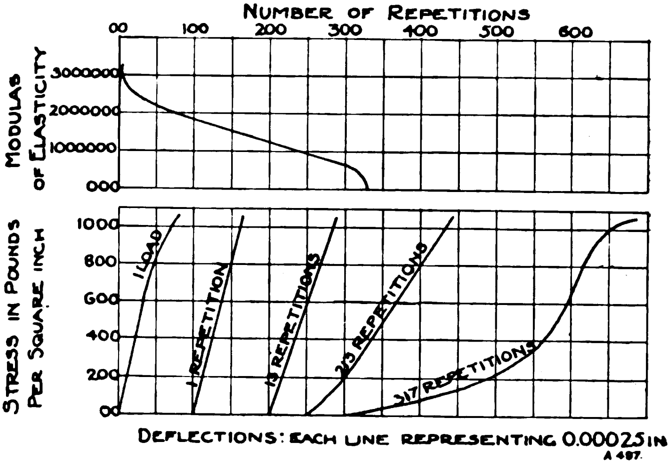


Fig. 5.

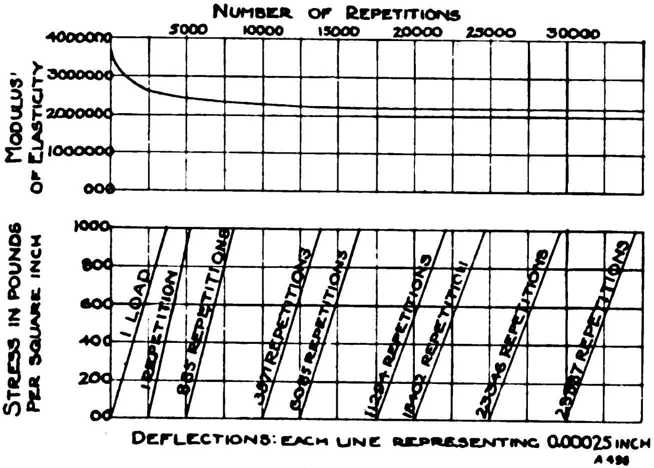


FIG. 6.

The lower portions of *Figs.* 5 and 6 show the stress strain curves under these two conditions.

Fig. 6 is perhaps of more interest than *Fig.* 5, as it approximates to the conditions of actual practice; it is, however, interesting to note in *Fig.* 5, which represents the results on a prism which failed after 332 repetitions, that the modulus of elasticity suddenly increases at the first repetition, then rapidly reduces to about its original value during the first few repetitions, the value then decreases constantly up to about 300 repetitions, after which it decreases very rapidly until it is zero at failure. This prism was loaded with a 70 per cent. load. With higher percentages the straight line portion of the curve becomes less, until at very high percentages it would disappear entirely.

The stress-strain curves in the lower portion of *Fig.* 5 show a decrease of the modulus of elasticity towards the end of the first loading, while the following repetitions show a constant modulus throughout the whole loading, though it decreases with the number of repetitions. When the specimen commences to fail the modulus increases at the commencement of the loading and then becomes constant until the full load is applied; this type of stress-strain curve is followed by curves showing an increase of the modulus at the commencement and a decrease of its value at the termination. Joined by a portion showing a modulus with a constant value as failure approaches the curved portions gradually approach each other, until finally the stress-strain diagram takes the S-form shown for 317 repetitions.

The behaviour under a repetition loading which will not produce failure is shown in *Fig.* 6, which is plotted from the results obtained from a specimen under a load about 50 per cent. of the ultimate resistance, which did not produce any signs of failure after 30,000 repetitions.

The curve for the modulus of elasticity has the same characteristics, the rise on the first loading, the quick drop and the following constantly decreasing value, but the rapid decrease of the modulus does not appear since failure is not approached. It will be noticed that for loadings such as these the modulus becomes practically constant after about 20,000 repetitions at a value of about $2{\cdot}2 \times 10^6$, while at the first repetition it approached a value of 4×10^6.

The stress-strain curves, with the possible exception of that for the first loading, show a constant modulus of elasticity throughout the entire application of the loading. The slopes of the lines show, with the exception of the first repetition, a gradually decreasing modulus, until it finally becomes constant for the higher repetitions. With respect to the permanent set, this was very noticeable during the first few repetitions, but rapidly disappeared in the case of the loadings under which the specimen showed an infinite resistance, shown in *Fig.* 6.

There was also no permanent set throughout the straight portion of the curve of the modulus of elasticity in *Fig.* 5, but it again became very apparent as failure was approached, when this curve bends rapidly downwards.

REINFORCED BEAMS UNDER FLEXURE.

A considerable number of reinforced beams were observed with respect to the deflections under repeated loadings and unloadings. *Fig.* 7, being plotted by Professor Van Ornum from the results obtained, is fairly representative though not typical.

The two curves show the total deflection and the permanent set or the deflection still remaining on the removal of the load. The hatched portion between the curves indicates the true elastic deflection of the specimen.

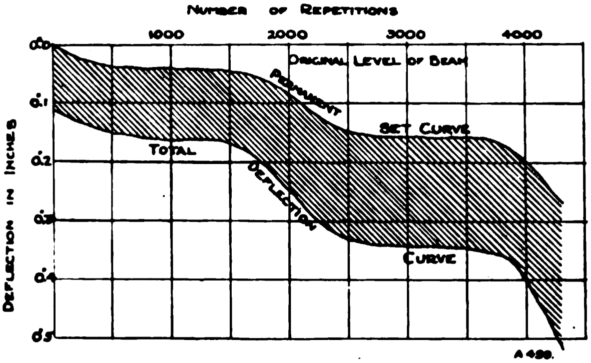


Fig. 7.

These curves are very interesting. They commence by a considerable downward slope due to the beam adjusting itself to the load conditions; during this phase small tensile cracks were formed. The curves then continue with a slight downward slope, the internal condition of the beam only changing slightly, the concrete still adhering effectively to the steel. The next phase is a distinct downward slope caused by the progressive failure of the bond between the concrete and the steel near the middle of the span; during this phase the tensile and diagonal cracks rapidly developed. The cracks having developed past the steel, almost perfect elastic equilibrium is again attained, the bars taking all the tensile stresses until failure approaches and the concrete commences to crush, when the curves take a rapid downward inclination until the beam offered no further resistance to the loading.

The curves in *Fig.* 7 are only broadly characteristic and alter considerably with different specimens, various factors sometimes intervene, while at times some of the portions of the curves disappear entirely owing to the absence of their causes. For beams loaded with less than a 50 per cent. load, only the first two segments of the curves exist, the slightly sloping line becoming eventually horizontal and continuing so for an infinite number of repetitions. The hatched portion between the curves also becomes of a constant width, showing that the true elastic deflection remains constant after frequent repetitions of the loading.

TESTS ON THE BOND BETWEEN THE CONCRETE AND STEEL.

These fatigue tests were carried out in such a manner that the true effect of the action between the concrete and steel in a reinforced beam was obtained, which renders them all the more interesting.

The specimens were 4 in. by 4 in. by 15 in. long, being reinforced by one ⅝-in. square bar with its centre 1 in. from the tensile surface. They were made with extreme care of the mixture stated above, and remained in the moulds for two days, they were then placed in water for seven days, after which they were stored in air until tested at an age of one month. The testing machine consisted of two steel pillars or strutts working in guides, with a metal cross-head faced with oak fixed to the ends of the strutts. The specimen was supported by clamping the ends of the rods, which were left projecting, in a rigid frame. The strutts were given a reciprocating movement in their guides, the blows imparting a repetition loading on the specimen acting as a beam supported by the rods. The prisms were so fixed that after the cross-head struck them it would travel $\frac{1}{100}$ of an inch before ceasing to act. A blow was therefore given the specimen followed by continued pressure. The blows were delivered at the rate of 150 per minute. Measurements developed the fact that each blow imparted to the specimen about 740 in.-lbs. of work, rather less than $\frac{1}{10}$ of this was expended in initial impact, some was lost through the beam supports, and the remainder produced flexure vibration, etc., to the beam, causing the treatment to be very severe.

Thirty specimens were tested in this manner, the average number of blows given to each being 50,000. It was found that the average initial unit value of the bond resistance after this treatment was 125 lb. per sq. in. of surface, and that after the adhesion had been destroyed there still remained a frictional resistance to slipping of 90 lb. per sq. in. of surface, the extreme range from these mean values being about 35 per cent.

For the sake of comparison, 18 specimens were tested by pulling the bars from the concrete without preliminary fatigue treatment. In this case the average strength of the bond was 150 lb. per sq. in. of surface, and the frictional resistance after failure of the adhesion was 100 lb. per sq. in., the range being the same as that for the fatigue tests.

The fatigue treatment reduced the value of the bond somewhat less than 20 per cent. in average value, and in no case as much as 50 per cent. Professor Van Ornum, however, does not suppose that this reduction in value would in no case be more, as it might easily be greater or less under varying conditions of mixing and storing. As would be supposed, there appear to be two distinct resistances to the sliding of the bars: (1) The true adherence of the concrete to the steel, and (2) the frictional resistance or grip of the concrete around the steel, which is quite independent of the adherence. The second of these resistances is considerably the greater, the adhesion proper apparently having a value of about 50 lb. per sq. in. It should be again noted that the grip of the concrete around the steel is particularly dependent upon any effect of change of volume of the enveloping concrete during setting and hardening, and is consequently influenced in a marked degree by the amount of water used in mixing and the subsequent storing or treatment while hardening.

FATIGUE UNDER A CONSTANT LOAD.

A few tests were made to test this. Two concrete prisms were compressed for one month under a load 90 per cent. of the ultimate resistance, and showed no appearance of failure. Professor Van Ornum also tested a reinforced concrete beam under the same percentage of ultimate load, and it did not fail even after being under this constant load for eight months. Its total deflection curve was similar to the first quarter of the curve shown in *Fig.* 7.

A curious phenomenon was noticed during this test. At a certain fixed constant deflection the poised weighing beam occasionally rises, instead of gradually falling; this must be due to some unexplained internal straining action in the beam.

Figs. 8 and 9 show a beam and a prism while under repetition tests.

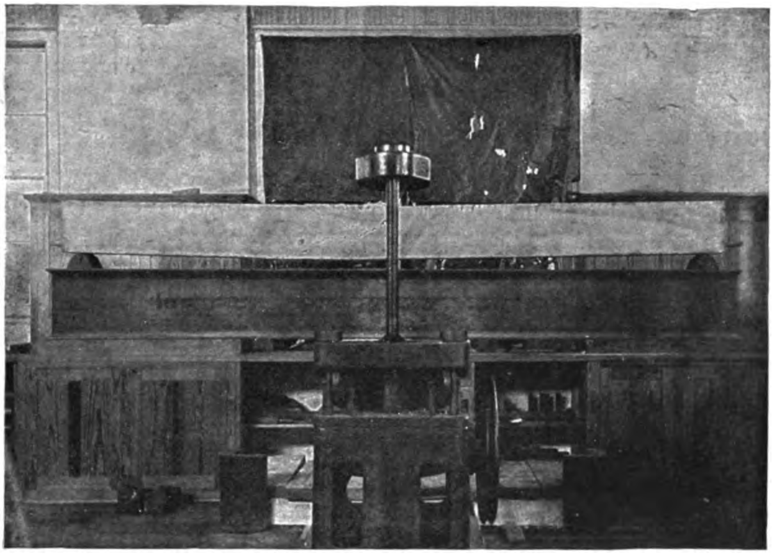


FIG. 8.

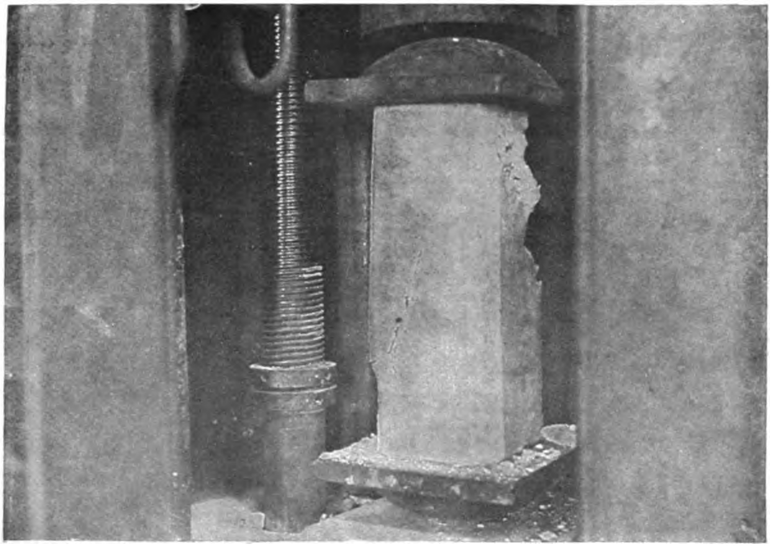


FIG. 9.

CONCLUSIONS.

The results of these tests point to the following conclusions :—

1.—That the fatigue of compressed concrete under loads of high percentage is a definite fact, but that its influence is limited to an intensity of about 50 per cent. of the ultimate resistance of the concrete. Allowing a limit of 30 per cent. for the range in values of the compressive strength of concrete of supposed uniformity, it is clear that no higher unit stresses should be used for the purposes of design than one-third the ultimate resistance as found in the ordinary way. While the working stresses employed in conservative and scientific design are always well within this limit, the danger of using too high values, or the employment of empirical formulæ by inexperienced persons, is very clearly shown.

2.—The effect of fatigue on the elastic behaviour of concrete appears to indicate that the proper modulus of elasticity to use in designing a structure should be in the neighbourhood of 2×10^6, and that after several repetitions of the loading the concrete attains a constant modulus of elasticity, pointing to the advisability of adopting a straight line stress-strain curve for the purposes of calculation.

3.—That fatigue has a marked influence on the bond between the concrete and steel when high percentage loads are employed, but that no appreciable effect is produced with loads producing stress within the working limits usually adopted in conservative design.

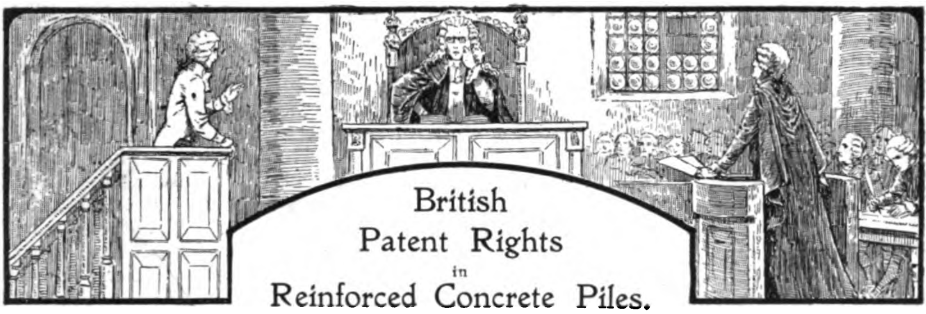
4.—That all rust should be well brushed off the reinforcements, as its presence has a marked effect on the bond.

5.—That there is danger in using excessive amounts of water in mixing the concrete, and that moderately wet mixtures only should be used, since either too dry or too wet concrete affects the bond between the concrete and steel detrimentally.

6.—That a long-continued constant load of considerable intensity will not produce any marked fatigue in the concrete, although undoubtedly such loads must produce some degree of fatigue in a specimen so tested.

7.—That the conditions obtaining during setting and hardening of the concrete affect the bond, since this is mainly due to the grip of the concrete around the rods.

It must be borne in mind that these tests were carried out on concrete in the proportions of 1 to 3 to 5, some of the stone being larger than 1 in. Such concrete would be considerably weaker than that employed in practical reinforced concrete work, and consequently the tests can only give comparative values, although the results doubtless give approximately true laws of the behaviour under fatigue.



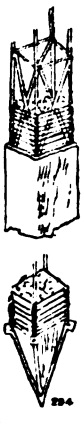
British Patent Rights in Reinforced Concrete Piles.

MOUCHEL and Another *versus* COIGNET and Others.*

JUDGMENT REVERSED ON APPEAL.

In a journal of this description important law cases must necessarily be dealt with from time to time. Of far-reaching importance, as previously indicated, we consider the one that is being fought in our Law Courts between two leading French Reinforced Concrete specialists, relating to British Patents for Piles. The case as tried in the first instance last year, was fully reported in our issue No. 4, Vol. 1, and the patents referred to were illustrated. The finding in the first instance was for Mr. Mouchel, but on appeal this decision has now been reversed by the unanimous finding of three judges, one of whom was the Lord Chief Justice. As we are given to understand that it is probable the case may be referred to the House of Lords, we refrain from any commentary at this stage, and would simply remind the reader of our previous editorials. We repeat our illustrations of the Brannon and Hennebique patents of 1871 and 1897 respectively, both of which are so frequently referred to in the case.—ED.

THE appeal in the above case was heard before the Lord Chief Justice, Lord Justice Farwell, and Lord Justice Buckley, on February 28th and March 1st. The appellants were the defendants in the first action, and were represented by Mr. J. M. Astbury, K.C., and Mr. J. C. Graham, K.C.; while Mr. C. A. Cripps, K.C., Mr. A. J. Walter, K.C., and Mr. H. A. Colefax, represented the plaintiffs, who were the respondents on appeal.



BRANNON'S PATENT, 1871.

Mr. Astbury, who opened the case for the appellants, relied strongly upon the cross-examination of Mr. James Swinburne, one of the experts called for the plaintiffs, Mr. Swinburne having admitted that, given the idea of Ferro-concrete, the invention lay in finding out that it was applicable to the construction of piles. Mr. Graham, who followed on the same side, read the cross-examination and re-examination of Mr. Dugald Clerk, another of the plaintiff's expert witnesses, to show that Brannon's specification described a concrete pile with a metallic skeleton. The plaintiffs had contended that Brannon's invention was an absurdity; and Mr. Graham urged that the plaintiff's alleged invention amounted to this:—Hennebique's invention consisted in realising that Brannon's was right, and that the plaintiff—in his supposition that a ferro-concrete pile was an impossibility—was wrong. But really the plaintiff's invention was for the construction of piles, and the method of placing them in position. Hennebique's claim 1 was for the construction, while claims 3 and 4 were for the method of placing them.

Mr. Cripps, for the respondents, contended that the plaintiff's idea was a loose collection of rods placed in a mould, held in position and concreted. The invention consisted in realising that this could be done, and, in accordance with the patent law, the inventor set out a method of carrying the invention into effect. Hennebique's structure was a concrete pile strengthened with iron, while Brannon's was a strong iron fabric filled up with concrete. The plaintiff's patent was for a new manufacture of particular construction and a particular material. He adopted the judgment of Mr. Justice Warrington. In the application of ferro-concrete to piles, one had a vertical girder adapted to receive injurious blows. He agreed with the Court that Brannon's pile could not be driven without the concrete. Hennebique's pile would not be practical with the cement only, and Brannon's would not be practical with the metal only. Hennebique was the first to suggest strengthened concrete for the purpose: but the Court intimated that this had been brought out in the specification. Counsel maintained that piles required qualities which were not to be found in the beams and other structures which formed the subject of Hennebique's prior patent. Mr. Justice Buckley thought that what Hennebique had done only amounted to discovery, and Mr. Cripps agreed that there could be no invention of the laws of nature, invention came in in the useful application of those laws. Mr. Cripps summarised his case to the effect that Hennebique's invention was, in fact, a new manufacture—namely, a new form of strengthened béton or concrete—namely, a pile capable of being driven and resisting bursting strains.

---

* Reported by Douglas Leechman, Esqr., A.I.Mech.E., Barrister-at-Law.

Mr. Walter followed Mr. Cripps on the same side, and took an independent line. He showed that Hennebique's latest specification embodied his earlier one. He dealt at some length with the evolution of the invention, showing the peculiar advantages arising from the combination of iron and cement. In ferro-concrete, particular arrangements of the two materials were provided to meet particular strains. The second specification, that is the one dealing with piles, acknowledged the state of the art, and cited a suitable construction for a beam. Hennebique had applied the same principles to the requirements of a pile, to stand bending strains in all directions and bursting. Special construction was necessary for piles, therefore the rods were arranged at the angles, and the ties were passed from one rod to another. The whole was moulded like a beam. Hennebique attached the shoe to the cement because it was the cement that was adapted to take the compression strains. The defendants were welcome to construct piles according to Brannon's specification, they would never hear of any action from the plaintiff for doing so. Claim 1 was for the construction of ferro-concrete made in a particular way for a particular purpose—viz., to resist the bending strains, to stand driving, and to carry weight. The pile was moulded with iron bars embodied therein to enable the combined structure to resist bending strains, and it was cross-tied by cramps to resist bursting strains. The particular method of combining concrete and iron made the concrete capable of resisting percussive strains. The spiral in Coignet's pile corresponded to the cross-ties in Hennebique's. Mr. Graham, interposing, pointed out that Hennebique's specification referred to any forms and dimensions, thus showing that the idea was not for a particular construction, as contended by Mr. Walter. Mr. Walter, resuming, urged that Hennebique's ties were adapted to resist bursting or circumferential extension, and Coignet's spirals did the same. The Court pointed out that there was no direct reference to bursting strains anywhere in Hennebique's specification. As to Brannon's pile, Mr. Walter contended that it was not intended to be driven. Stempel's post was not the same. It did not teach the world how to construct a ferro-concrete pile that could be driven. The outside of Stempel's structure was a mere covering of glass, or similar material. That which would be a mere clumsy infringement if produced later, would not be an anticipation if produced earlier, than the patent in question.

Mr. Graham, in reply, pointed out that Hennebique's first claim had nothing to do with shapes or sizes, but the idea that one could use an old structure for a pile. Mr. Graham had not concluded his speech when the Court adjourned for lunch, and on resuming after the interval, the Lord Chief Justice informed him they need not trouble him further, and proceeded to give the following judgment:—

JUDGMENT BY THE LORD CHIEF JUSTICE.

This is a patent action, in which Mr. Justice Warrington has upheld the patent, and has held that there is an infringement. We have been addressed to-day in an extremely able argument by Mr. Walter, who has asked us to put a very narrow construction upon this specification, and to support the patent upon that narrow construction, and hold that there has been an infringement. Speaking for myself, if I had been convinced by Mr. Walter's argument that the narrow construction ought to be put upon the specification, I am by no means clear that the patent could not be supported; but I express no opinion as to whether there was infringement, because we have not heard Mr. Graham's reply upon that matter, and we do not need to decide it. I have come to the conclusion, for reasons for which I will endeavour to explain as clearly as I can, that it is not possible to put upon this Specification the narrow construction which would enable the Patent to be held valid.

Throughout the greater part of the argument (and it is no discourtesy to Mr. Walter to say that his later argument was rather inconsistent with his leader's earlier argument) both from the Apellant's counsel and from Mr. Cripps, the leading counsel for the Respondent yesterday, I understood that the way the case had been presented in the Court below was that the merit, be it invention or be it discovery, was the announcing to the public that a ferro-concrete pile could be used for the purpose of the pile (I will say, for the moment) mentioned in this Specification. It is doing no injustice to the plaintiff's case to say that, so far as the Court is to be guided by the explanation of scientific witnesses, that most unquestionably was the way in which the merit of the invention or discovery was explained to the Court. The principal witnesses, whose evidence was read for the plaintiff, Mr. Dugald Clerk and Mr. Swinburne, both enlarged, and very properly enlarged, from their point of view, upon the fact that they never would have thought it possible that a ferro-concrete construction could be used for a pile; that it was a complete surprise to them; and not only so, but, in passages which I shall have to refer to presently, they said that, given that, and taking that to be what I may call known, an entirely different construction must be put upon certain of the anticipations that were pleaded.

I shall have to say something with reference to the law applicable, if that is really what may be said to be invention, because it seems to me quite impossible to treat that as being invention in the sense of being that which could be made the subject of valid Letters Patent, if what the plaintiff has done is to point out that a known construction can be used in a particular way. But I think it is better that I should at once deal with what is the construction of this Specification, because all that I say with regard to my reasons for thinking this patent cannot be supported must, of course, be tried and tested by the construction I put upon the Specification. If it is a wrong construction, it will be open to review; if it is a right construction, it is at any rate the construction by which I think the rights of the parties must be determined. I have only to say (it is not necessary to say it in this Court, but I think, perhaps, it is better that I should say it) that, in dealing with this question of the construction of the Specification and the construction of written anticipations, the Court is to judge, making itself acquainted with such technical and scientific terms as will enable the Court to understand the Specification as it would speak in the trade or in the art to the workmen who had to carry it into effect. I mention that because, although we were obliged to listen to a great many expressions of opinion of witnesses read to us as to what the Specification meant, after all, the construction of the Specification is for the Court, and for the Court only.

The Specification begins by stating that Hennebique had experience, which he undoubtedly had, with regard to béton, or concrete strengthened by iron and steel, and its employment in building construction in various ways, and he refers to his own Specification (No. 14530, of 1892) as giving the information which he desired to be read into the Specification, and quite properly read, in order that it might be understood. Then, at page 1, line 19, he says:—

> I have applied these principles to the construction of piles, sheet piles and solid uprights or standards.

Very little attention has been paid by the respondents to those words, "solid uprights or standards." If it would be right to limit these words "solid uprights or standards," having regard to the language used in the claim—to cut them out, so to speak, from the description of what he claims—if other parts of the Specification show that he was only dealing with that which has been so much pressed upon us—namely, a pile which would be capable of being driven—there would be some ground then for suggesting that Mr. Walter's more narrow construction was right. It seems to me, looking at every part of the Specification, that it would not be construing the Specification justly, either to the patentee, or, as we ought to say, to everybody—to people who may infringe, and who must be told what they are to avoid—if we were to hold that he did not intend to include in that which he is about to describe, not only piles and sheet-piles, which may or may not be driven, as I shall have to point out presently, but solid uprights or standards. Then it goes on to say "which"—and this is why, amongst other reasons, I think it is impossible to say that these words must be disregarded:—

> which, corresponding to the special conditions of their arrangement or employment may according to the strains, the loads and the pressures to which they are subjected, be assimilated to girders whether placed on two or more supports or embedded at one end and so forth.

In other words, he is pointing out that he is going to use, in an upright position, that which has previously been used in what I may call the horizontal, or the nearly horizontal, position. Then he goes on:—

> The construction of these piles and sheet piles, their combination and the method of placing them in position, as well as the applications of which these separate and combined elements are capable, for the object of the present invention, and are shown in the accompanying drawings.

Then comes the description, to which I need not refer in detail, having regard to the view which I take of this Specification. When he has described, as he does on page 2, part of his pile, he says:—

> In its lower part the pile is armed with a shoe *c* (*Figure* 1) in the form of a point in order to facilitate its being driven into the ground. The head of the pile is narrower, which allows of an interval between the heads of two adjacent piles. The piles are inserted according to the nature of the ground either by dropping or by means of ramming.

When the distinction has been attempted to be drawn between a pile and a post—that is to say, between a pile and an upright structure—it has been said:—

> You are not to read this Specification as telling people that they may use this construction for upright posts.

I think it is impossible to put that construction upon it, when the patentee has used the words "solid uprights or standards" in line 20, and has said that, "according to the nature of the ground, the piles" (by which he means the construction) "may be dropped in." That has nothing to do with ramming. It is not put as meaning "and subsequently rammed"; it is put as an alternative to ramming. Then, when you come to page 3, line 22, the same view is, in my judgment, further carried out, because he goes on to say:—

> The piles and solid sheet piles of strengthened béton which, owing to the arrangement of the protective cap which I have described may be driven into the ground with the same facility as piles or sheet piles of wood—

I pause there to point out that it is not a statement to the public that the new construction may be driven and is to be driven, simply because it is the new construction; it is quite plain that at that time the patentee meant to tell the public, and must be taken to have meant to tell the public, that it was owing to the arrangement of the protective cap that the pile could be driven in. I do not use that in the least for the purpose of putting too narrow a construction upon the Specification; but it is most important to point out that it supports the view that "may be driven" is when—as the patentee then thought, and as he then told the public—the protective cap is to be used. I agree entirely with the argument of Mr. Cripps and Mr. Walter that that would not make any difference if, on the whole of the Specification, we ought to confine the meaning of the Specification to a post or upright which can be driven, and only to that. But it seems to me a very strong argument in favour of the view that the driving of the construction into the ground is only one of the incidents which he was describing, confirming the view I have already expressed, based upon the two earlier passages, and pointing out that he was dealing with that incident of the construction by providing for it in a special way. Then he goes on:—

> have numerous advantages over these latter, as not only does the method of moulding and of protecting enable any suitable power of resistance and any desired forms and dimensions to be given them.

To my mind, pointing to the intention of including in the Specification his new structure for upright purposes that could be made in any particular form or of any particular dimensions. Then there is a passage, at line 30, which also shows how much he had in his mind the question of construction as distinguished from the driving into the ground. As he says:—

> Their non-liability to alter in air or water allows of constructions of this strengthened béton being raised above the level of the water when works executed in timber cannot bear the alternations of dryness and humidity.

It is perfectly well known that wetness and dryness alternatively have a certain effect upon wooden structures, and he points out that concrete will not be affected in that way.

Under these circumstances, what does he claim in Claim I.? We are asked to say that he only claims piles in the sense of a construction which must be capable of being driven; that it is unnecessary, if it is an upright or a standard, to put that construction upon it; unnecessary, if it is a thing which could not be driven in consequence of the nature of the ground; unnecessary if driving is only what I may call an occasional incident of the use to which these things are to be put. The words of the claim are:—

> Piles formed of bars of iron embedded in beton and cross-tied by cramps in such a way as to always form a solid girder practically constructed for supporting the weight of an upper building or construction or any desired lateral horizontal pressures, substantially as hereinbefore described and shown in the accompanying drawings.

I must point out that, in the face of that claim, the merits that he draws attention to have nothing to do with the way in which it is inserted into the ground. It is perfectly true it begins with the word "Piles"; and if, on the face of the Specification, or by the language, as it is sometimes called, of the patentee in the Specification, "piles" there was to connote only a thing that could be driven, or to exclude that which could not be driven, or was not wanted to be driven, a different construction might have been put upon it. But if I am right in pointing out that that limited construction cannot be put upon the word "piles," that observation is strengthened by what he points out as to what is going to be gained:—

> a solid girder practically constructed for supporting the weight of an upper building or construction or any desired lateral horizontal pressures.

I need not point out, because it is self-evident, that those advantages have nothing in the world to do with the pile being driven in, or with the pile being capable of being driven in; they are due to the fact that he has found or discovered, that his ferro-concrete construction which he has used horizontally—used as a solid girder horizontally—can be used as a solid girder vertically.

I may further point out that that construction of the first claim is strengthened, in my opinion, by the third claim, because you have these words in the third claim:—

> In piles of the kind described, a metal cap substantially as hereinbefore described and shown in the accompanying drawings, for use in ramming, enabling the head of the pile or sheet pile to be entirely encased and to distribute the pressures of the blows of the ram—

It is said that this construction obviates or removes the danger of what has been called the bursting open of the pile when there are blows impinging upon the head of it. All I can say is this: That if that merit, so to speak, is going to be used for the purpose of differentiating this from some other structure—if that is going to be used as a test of the merit of the invention—I should have expected to find some reference to it in the Specification. But this bursting is not referred to at all. I have in my own mind no doubt whatever, on the face of the Specification, that the view which was intended to be presented, and which Mr. Cripps has presented to us, was that he sought to claim the use of piles so constructed—meaning thereby his ferro-concrete construction—for the purpose of a standard or pillar, which, when placed in the position of piles, would have the advantages which the Specification and the claim point out.

I pause here, only for a moment, to say that, if we were to adopt the argument presented to us by Mr. Cripps that the invention lay in seeing that ferro-concrete could be applied for vertical use as distinguished from horizontal use—if we were to hold that that was a new result, or a new process, or a new article—I think we should be flying in the face of the language of Lord Lindley in the Lane-Fox case, where he points out the distinction between discovery and invention, and which was, if I may say so, very happily explained also by my Brother Buckley in a later case—which, I think, was the Jandus Lamp case. The passage is to be found in Mr. Frost's book. Therefore, I come to the conclusion that the wide construction of the claim would be one that is open to very serious attack, on the ground that it does claim discovery and not invention. But the real and serious difficulty which arises, if I am right in my construction of that claim, is from the fact that if the claim is one for the use of standards and uprights and posts, which are equally described, for the purposes of the Specification, as uses to which these structures are to be put, I am unable to see the slightest difference between the construction in Stempel and the construction in this Specification. All I can say is that I put it to Mr. Walter, and I put it to Mr. Cripps, and I understood their answer to be only in accordance with what I myself should have thought from reading Stempel's Specification. *Fig.* 1 is a prospective view of a metal frame prepared ready for filling, or incorporating with concrete or other material not subject to decay, for the construction of fence-posts, etc. Then, "a longitudinal section of the cross-tie"—this is a tie for work upon railways—

> and shows the metal frame, concrete filling, and bolt holes for the attachment of the chairs to the ties;

and later on:

> By this means the metal, which may be of iron or any other suitable material, is preserved from rust and attrition, and as the

> material by which it is inclosed, except for its frangibility, is virtually indestructible, not being subject to decay, the said metal frame obviates said frangibility, and gives the article thus manufactured a backbone that under ordinary circumstances cannot be broken, the correlative positions of the materials, and their correlative qualifications each making provisions to countervail the lack in qualification of the other, so as to co-operate to form a post, railway-tie, beam, or other articles that combines the strength of the metal with the undecaying, and therefore indestructible, properties of the concrete, glass, etc.

Now, that is a description of a ferro-concrete post made exactly in the same way. A post may be rammed into the ground, or it may not be rammed into the ground. It is not, of course, rammed in the sense that a pile is which is driven in by a heavy weight; but, in my judgment at any rate, if we are to apply to that language the knowledge of a later date (1889, I think the year should be) it is not possible, consistently with the decisions which have been given in these cases, to say, if I have rightly construed this Specification, that the patent can be supported, for it does not inform the public, as it ought to have done, that they can use identically the same construction for an analagous purpose which is already old. Again, I say, if I could put upon this Specification the narrow construction that Mr. Walter contends for, I am not sure that Brannon would create any very serious difficulty in his way. Or, to paraphrase that, and put it in other words, if all the patentee claimed was the particular kind of construction, I think there are quite sufficient differences to make Brannon's anticipation less serious than Stempel's. But I may say, if the great merit of the invention is to be that which has been pressed upon us—namely, the seeing that ferro-concrete could be used for purposes such as I have described, that is to say, vertical instead of horizontal, or could be used for piles even in the limited sense that Mr. Cripps and Mr. Walter contend for—well, the disclosure of knowledge in Brannon's Specification is much more considerable than might at first sight appear. I will not read it again, because it has been read so recently; but I refer to the passage on page 3, lines 13 to 33, where he points that the mixing together of concrete and metal substances has the effect of making these homogeneous, and that the embedding in the concrete of the other material secures a perfect bonding of the same into a solid and coherent mass; and that he thought that a construction of concrete and iron could be used for pile purposes, is not seriously disputed. It is perfectly true that that particular construction which he shows does not show that you could do with less. It may be said to be more elaborate, and, therefore, not to have given the full information, if this patent had been for the improved design which the plaintiff has specially described; but I do consider that Brannon is an addition to the stock of knowledge which makes it impossible for the plaintiff to be entitled to rely upon that wide construction which he claims to put upon his patent.

I only wish to say a word or two about some of the passages which have been read from the evidence. I have already indicated that I have used them for the purpose of informing my own mind I think, however, it is right to say that, as I understand Mr. Swinburne's evidence, particularly on pages 108 to 110, and from long experience, I know that Mr. Swinburne gives his evidence with the greatest possible care, and I have not the slightest doubt that Mr. Dugald Clerk does too. But I think, in this case, Mr. Dugald Clerk has not taken so moderate a view of the matter as Mr. Swinburne did. Mr. Swinburne, called for the plaintiffs, as I understand his evidence, most undoubtedly does say that, given ferro-concrete, to be used for such a purpose, you would find in Brannon's Specification amply sufficient instructions to enable the pile of the plaintiffs to be made. I quite agree that, if Mr. Swinburne was right in saying that you were to exclude from the knowledge of 1897 everything with regard to the use of ferro-concrete up to that time, you might possibly put a different construction upon it. And I do not quite understand how it is that the learned Judge did not seem to be as much impressed as I was, at any rate by the evidence of Mr. Fox with regard to the amount of knowledge that would be given anybody by a perusal of Brannon's Specification, and of what I may call the other anticipations to which our attention has been called in the case.

I have only to refer (and I wish to do so with the greatest possible respect) to the view that has been taken of this case by the learned Judge. He has dealt with it with the greatest ability and care, as he does with every case, and I desire to show that I have most carefully considered this judgment, as I do all judgments that are appealed against, and that I respect the reasons of the learned Judges whose judgments are brought here for review, and, that being so, I feel bound to give my reasons for saying why I am not able to take the same view. My brother Warrington, at the beginning of his judgment (which is reported at page 661 of the Patent Office reports) was obviously very much impressed, and very naturally impressed, by the new use which, according to popular belief and popular experience, ferro-concrete was being put. He refers to it as being

> Concrete strengthened by the incorporation in it of rods or bars of iron, so arranged as to supply the power of resisting tension strains, a power possessed in a marked degree by iron, but hardly at all by concrete, which, on the other hand, possesses a great power of resistance to compression strains. Then he says what a

Then he says what a blue pile is :—

> This is a beam or post intended to be placed in position by the application of force. The force may be applied in more ways than one, but by far the most common is by driving—that is to say, by the impact of a heavy weight on the upper end. I find, as a fact, that no pile would be considered by an engineer as effected unless it be capable of being driven. I find, also, that until the Plaintiff's Patent, although strengthened concrete and its various uses had been familiar to engineers for several years, no one had thought of making a pile of that material, the reason being that it was considered unfit to bear the bursting strain which would be occasioned in driving, and, therefore, that a pile of strengthened concrete would not possess one of the essential features of an efficient pile—that is to say, the capability of being driven.

I understand that practically to mean that he is approaching the consideration of what he afterwards refers to from the point of view of dealing with it as applying to that class of structure, and to that class of structure only. Then the learned Judge reads the Specification, and at page 663 is a passage which has been so often read from page 446—which is the page in the book that my learned brother has been referred to. He said :—

> I am of opinion, both on the construction of the Specification, and in fact, that the Patent is for a new manufacture—namely, a pile capable of being driven and of a particular construction, and of a particular material.

Now, he cannot, I think, mean "particular construction" in the limited sense that Mr. Walter has been putting before us. What I think he meant was the particular construction which was this use of the ferro-concrete—the iron and the concrete, and the particular material, namely, ferro-concrete—which had been used in that construction. And it is upon that view that I am unable to concur with him, because it seems to me that he either meant the pile, which is a thing which must be driven, or capable of being driven, and did not consider that which I think is of the greatest importance—namely that, as claimed on the face of the Specification, the construction which comes within the description will be a thing which may be driven, or may not be driven, which may be a standard, or may be an upright, and which will fulfil all the functions and advantages and requirements which are specified in the claim. Then the learned Judge deals with Brannon; and, having read a passage from Brannon's Specification, he said :—

> Now, to pause there for one moment, there is no reference in that part of the description to the use of the invention for the purposes of piles. There is no indication in that part, or, so far as I can find in any other part of the Specification, of the Patentee's familiarity with strengthened concrete.

I am unable to understand that, having regard to the passage, or the construction which I have put upon the passage, at page 3 of Brannon's Specification, to which I have previously referred; and I think the learned Judge has adopted this view of Mr. Dugald Clerk, and, with very great deference to him, seems to me not sufficiently to have considered what was said by Mr. Swinburne. And he accepted the view of Brannon taken by Mr. Dugald Clerk, which is not supported by the other witnesses for the plaintiffs or the defendants. Mr. Dugald Clerk said that "he" (that is, Brannon) "does not show anything which would be called nowadays an armoured concrete pile. The armoured concrete pile is a loose metallic structure depending on the concrete and iron, not a rigid structure." It may bend, and if so, I cannot understand it; but how it can be fairly called a loose structure, I cannot understand.

> The real cause of the success of armoured concrete is that it does away with all rivetted and ironwork joints, and ironwork generally, and for a few pounds you can put up iron and steel enough without any rivetting whatever.

That, in my judgment, was most certainly a view which shows that the learned Judge was not deciding this case upon any narrow construction of the Specification, but was adopting the view that, because it was made of the ferro-concrete and used for a pile, therefore Mr. Dugald Clerk was right in saying that Brannon did not anticipate it.

I should like very much to have known why my brother Warrington did not consider that Stempel's Specification required consideration; but all he says about it is:—"The other Specifications relied upon are all for various applications of iron and concrete; but none of them, in my opinion, suggests a pile capable of being driven with a monkey." The learned Judge seems to have thought that he was to construe this specification as being confined to a claim for that which could be driven, and that there would be no infringement, or it would not be within the claim if, though the construction was identical, it had been put in the ground in the way which the patentee, on the face of that Specification, contemplated. I am not able to take that view, and I therefore come to the conclusion that this Specification does claim a construction of a pile—meaning thereby a vertical upright which may be used for a standard, or an upright which may or may not be driven into the ground exactly in accordance with the way in which Stempel's post had been constructed; and I therefore think that, if that wide claim is put upon the Specification, as I think it must be, the patent is bad.

For these reasons the appeal must be allowed.

JUDGMENT BY LORD JUSTICE FARWELL.

FARWELL L. J.: I agree; and I can put my views in very few words. In reading Hennebique's Specification, it appears to me to be plain that he commences by telling us that it is then common knowledge that,

> by the use of a rational mixture of iron or steel and cement, the former being extremely suitable for resisting the efforts of traction or tension, and the latter offering a considerable resistance to stress or compression,

excellent results will be obtained in the materials which will be thus formed. He goes on to tell us that he has already got a patent by which girders have been made in the manner pointed out by him in that Specification. He then goes on to apply those principles to the construction of piles; and, when you refer to his first claim, you see that he says, in effect: Make your pile as I have made my girder —" piles formed of bars of iron " and so on, so as to form a solid girder.

Reading the Specification as a whole, it appears to me that he has said nothing more than this. "I have already used the knowledge that I had as to the valuable qualities of ferro-concrete" (which was not then so called, but which I use for shortness as a phrase) "for horizontal matters. Apply that which I have used for horizontal matters to uprights, and you will find that they act admirably." To begin with, it appears to me that it is impossible that a man can, having taken the benefit of this invention for a girder, then say: I will now get an extended period for my patent by applying that invention to uprights. There is nothing sufficient to support a patent in that. That difficulty being felt, it is met in this way, as I have followed it:—It is said that Hennebique discovered a further scientific truth—namely, that a ferro-concrete pile would resist percussion strains. Having said that he discovered that, it is then attempted to confine this Specification to piles which are to be driven in by ramming or hammering; and that is the view taken by the learned Judge below. I am wholly unable to follow that at all. There is no such limitation in Claim 1; and, reading from page 2 of the Specification, from line 5 and onwards, it is plain, to my mind, that it was intended to apply the invention not only to piles which are rammed, but also to piles which are dropped. And it is conceded that piles are made without pointed ends at all. In fact, although I do not at all surrender my right to construe the Specification according to my own views, I have the satisfaction of knowing that Mr. Dugald Clerk takes this view, because he says, at question 307:—"You need not hammer the thing in order to infringe Claim 1?—No." I entirely agree with him. It is meant to be a claim for both. But, even if that were not so, just consider how it stands. The new discovery is discovery pure and simple. You cannot take out a patent for the discovery that ferro-cemented piles will resist percussion strains; the only thing you can take out a patent for in such a matter would be a pile of a particular form, so as to get the benefit of that new truth which is thus so first discovered. It is said here that this is intended to extend to all piles made in any form with upright irons, on all the sides, and cross-ties secured with clamps around the sides. That, I should have thought, is far too wide. But the difficulty, to my mind, is this: That if Stempel had, in fact, made his posts as he shows, and had hammered in a post—which is not unnatural—and had found it resisted percussion strains, according to this argument Stempel, although he could not be restrained from making posts according to his own patent, could be restrained from using the posts so made as piles. The proposition, to my mind, is absolutely novel as far as I know; and on that short ground I think this patent is bad, and I entirely agree with the view which my lord has taken.

JUDGMENT BY LORD JUSTICE BUCKLEY.

BUCKLEY, L. J.: The course which this case has taken in argument by the respondents' counsel has been so extraordinary as to be, in my experience, unique. We have heard from Mr. Cripps, the leading counsel for the respondents, an argument, based upon the construction of the Specification, which was a broad one which defined the invention, which he said he was entitled to protect, as being a new form of strengthened concrete—namely, "a pile capable of being driven and of resisting bursting strain." Mr. Walter, following him as his junior, presented to us an argument which, so far as I can trace it after looking at the report in the patent reports of what took place in the Court below, and having heard what was advanced in this Court, was absolutely novel until he arose to address us; and that argument was that Mr. Cripps' construction of the Specification was all wrong; that the true construction was a very narrow construction; and that the patent was simply a patent for a pile constructed in a particular way, namely, "Substantially as described and shown in the acompanying drawings." It was not a broad patent at all—it was confined to a particular arrangement. Now, those two matters are so diverse that, if I was going through them both, they would really require two judgments. I do not propose to take that course, and I think I can deal with it shortly.

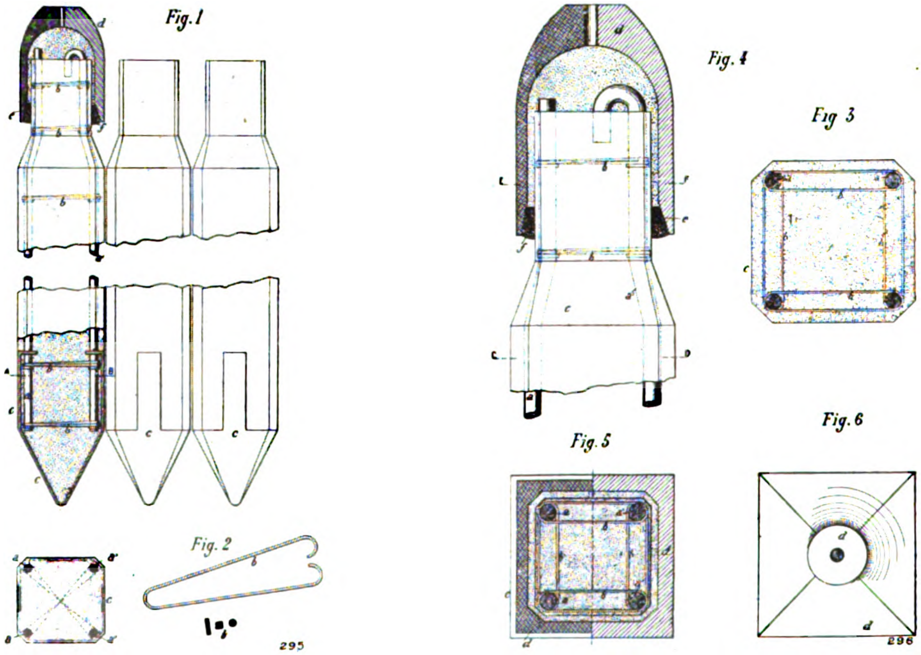
Let me assume first the broad construction of the Specification, as to which I am not going to add anything to what the Lord Chief Justice has said, except to say that I agree with it. My Lord has already pointed out that in this Specification a pile does not necessarily mean a thing which you are going to drive; you may be going to drop it. But, setting that aside, let me assume for a moment that a pile means a thing capable of being driven, whether or not, in fact, it is used for dropping or for sinking by means of the use of a water-jet. If that is so—if the word "pile" contains within itself the idea of a thing which is capable of being driven by pressure, by blows upon the end—then Brannon actually claims to have constructed piles as things to be driven. In that view of the case, all that remains to be said on this head is that Brannon's skeleton structure is, so the respondents say, a rigid thing, and that Hennebique's structure is not a rigid thing. In the first place, I do not think that is true. I do not think Brannon's structure is a rigid thing; he describes it as being "a sustaining mechanical skeleton or framework, firmly bolted or pinned together." The word "sustaining," I think, there means not of such strength as to sustain as a skeleton the blows at its end, or the weight which it will have to support, but of such strength as will sustain the skeleton while it is being exposed to the action of the concrete, and probably also will sustain it when the bound body of iron and concrete is used in position. So that the skeleton is not, I think, a rigid thing. But suppose it is, for the present purpose, it is none the worse for that. It is not ferro-concrete, I daresay, in the modern meaning of that term—that is to say, it is firmly bolted or bound together, and not merely used as a skeleton which, when filled with concrete, will become a rigid thing. Then that only leaves this: That, as a matter of the construction of the pile, the invention is of a rigid body produced by filling with concrete the non-rigid skeleton. If that is so, that was old. Stempel did that, and he did it for a post or a pillar; and it seems to me that Wilson did it, too. Ferro-concrete construction, in the proper sense of that term as now understood, meaning not merely a combination of iron and concrete, but such a combination of iron and concrete as will throw the tensional strain on the iron and the compressional strain on the concrete, was well known before 1897. Hennebique himself had used it in 1892; and in this view of the case, therefore, all that the patentee can be said to have discovered is that it is possible to drive a ferro-concrete pile. Passages, to a large extent, were read to us from the evidence in which that was the exact point to which the witnesses were directing their attention. They said:—

> Nobody would have supposed that a body so constructed could bear percussion strains—you would expect it to splinter, to break up, to distort, and to become useless; and the thing which Hennebique discovered was that that was not true, that the thing, as constructed, did not break up when you gave it violent blows on the end.

To that part of the case the short answer is that everybody admits that that is discovery, and not invention; and you cannot have a patent for discovery. If, therefore, the patent is to bear the broad construction that Mr. Cripps would put upon it, it seems to me that it is bad, because it was anticipated. On the other hand, if the view presented by Mr. Walter is the right one, and it is a narrow thing, then it seems to me it has not been infringed.

As regards the clamps in Hennebique, they are to be what he calls "veritable clasps or clamps." They are to be something which, as between rod A and rod B, will prevent rods A and B from parting. What the defendant did was not to clamp rod and rod at all; he put a spiral wire round all the rods, which would have, I agree, just the same effect under bursting strains as the rectangular clamps which Hennebique used, but which would not have the same effect under some circumstances, and under no circumstances would prevent rod A from parting from rod B. It might keep the whole system of rods, A, B, and C. up to the letter M in position, but there never were clamps as between rod A and B. It seems to me that if the narrow construction of the Specification is the true one, there is no infringement at all. And in either case, therefore, the action fails, and I consider that the appeal ought to be allowed with costs here and below.

At the conclusion of this judgment the Lord Chief Justice ordered the costs incurred in the Court below to be repaid.



FIGS. 1 TO 6 OF THE HENNEBIQUE PATENT, No. 10203 OF 1897.

The Building Trades' Exhibition at Olympia,

APRIL, 1907.

The Building Trades' Exhibition at Olympia was a great success, and most instructive to all members of the technical professions, whether belonging to the architectural or engineering side.

This journal, recognising the importance of the show, arranged an exhibit in one of the central avenues, the principal feature of which was a useful collection of photographs of recent works executed in concrete and reinforced concrete.

As a curiosity there were also shown in our exhibit some frames containing envelopes that had covered subscription orders for the journal from out-of-the-way places in the most distant parts of the world, where British Engineers require home specialities for carrying out their work.—ED.

The organisers of this great show are to be congratulated on the success which has been secured, and upon the wise decision to change the *locale* from the Agricultural Hall to Olympia.

Although not inconveniently overcrowded by any means, the great building, which in itself is a magnificent exhibition of structural work, was very well filled in every part, and the collection of materials and manufactured articles to be found therein thoroughly deserved the attention of all connected with building construction.

In the subjoined notes we have dealt only with such exhibits as come directly within the scope of this journal.

THE EXHIBITS.

PORTLAND CEMENT.

The Associated Portland Cement Manufacturers (1900), Ltd. (row D, special position No. 16), provided an exhibit of much interest, including samples of chalk, clay, and other raw materials used in the production of their well-known brands of Portland cement, the same materials, after preliminary treatment, in the form of slurry ready for calcination in the kiln, clinker at various stages of calcination, and finely ground clinker constituting the finished cement. Those who are only generally familiar with the processes going on in a modern cement manufactory will have found these samples of educational value, while cement experts will have had convenient opportunity of satisfying themselves as to the care taken by the Associated Company with respect to every detail connected with the manufacture of these well-known products. Among other samples of cement exhibited we may direct attention to the very finely ground "Ferrocrete" brand, which is recommended specially for reinforced concrete construction. A useful feature of this stand was the department devoted to cement testing, and equipped with a complete installation of apparatus for the conduct of all the tests specified by the Engineering Standards Committee. Practical tests were conducted from time to time, thus demonstrating the ease with which cement may be examined after the routine has once been mastered. It would be impossible to attach too much importance to the necessity for cement testing, especially at the present time, when fictitious "Portland" cement is unfortunately being offered so largely to unsuspecting buyers in this country, and has become a serious menace.

Before passing away from the stand visitors were able to examine the model portable "Gravity" concrete mixer, a simple apparatus of effective character, by which the constituents of concrete can be thoroughly incorporated at a saving stated by the makers to be about 50 per cent. on other methods of mixing that involve the use of complicated mechanically-operated machinery.

OTHER CEMENTITIOUS MATERIALS.

Other types of cement and plaster were represented, as the following notes of the more important ones make clear:—

The Granite Silicon Plaster Co., Ltd. (row B, No. 50), had a pavilion exemplifying the use of their plaster, which, although somewhat more costly than ordinary plaster, seems really more economical in the long run, and is well adapted for solid partitions.

The Gypsum Mines, Ltd. (row G, No. 123), make various forms of cement and plaster produced from the minerals quarried from their Sussex and Derbyshire mines. "Sirapite" plaster for partitions and ceilings is a material which can be applied with equal facility to wood and metal lathing.

Messrs. J. A. King & Co. (row D, No. 88), in addition to their fire-resisting specialities, showed examples of plastering with a new form of "fireproof" cement, which, we believe, has not yet been officially tested, but will probably be found to constitute a useful addition to the protective coatings available.

Messrs. Clarke & Co. (row C, No. 68) utilised the interior of a special building for the purpose of showing samples of work executed in their "Xelite" plaster recommended as a substitute for Keene's and Parian cements.

CONCRETE AGGREGATES.

Among materials for the preparation of concrete the visitor might have advantageously examined the samples of Leighton Buzzard and Flitwick sand, exhibited by Mr. Joseph Arnold on the ground floor, and then passed up to the gallery to devote himself to the numerous specimens of broken stone provided for inspection by various quarry owners, among whom we may mention the following as laying themselves out more particularly for supplying this class of material: — *The Mountsorrel Granite* Co., Loughborough (bay 15), broken stone and chips; *The Tilbury Contracting and Dredging Co., Ltd.* (bay 16), broken Kentish ragstone and chips; *Darbishires Granite Quarries*, Penmaenmawr (row B, No. 2), granite chips and sand; *Messrs. Field & Mackay*, Ludlow (row B, No. 27), broken basalt; *The Clee Hill Granite Co., Ltd.* (row B, No. 27A), broken basalt and chips; *The Clee Hill Dhu Stone Co.* (row B, No. 27B), broken basalt; *Messrs. John Freeman, Sons & Co., Ltd.* (row B No. 30), Cornish broken granite and chips; *Messrs. W. and J. Glossop, Halifax* (row B, Nos. 35 and 36), "Lembton" broken granite; *The Jees Hartshill Granite and Brick Co., Ltd.* (row B, No. 37), broken granite (various sizes) and washed chips for concrete.

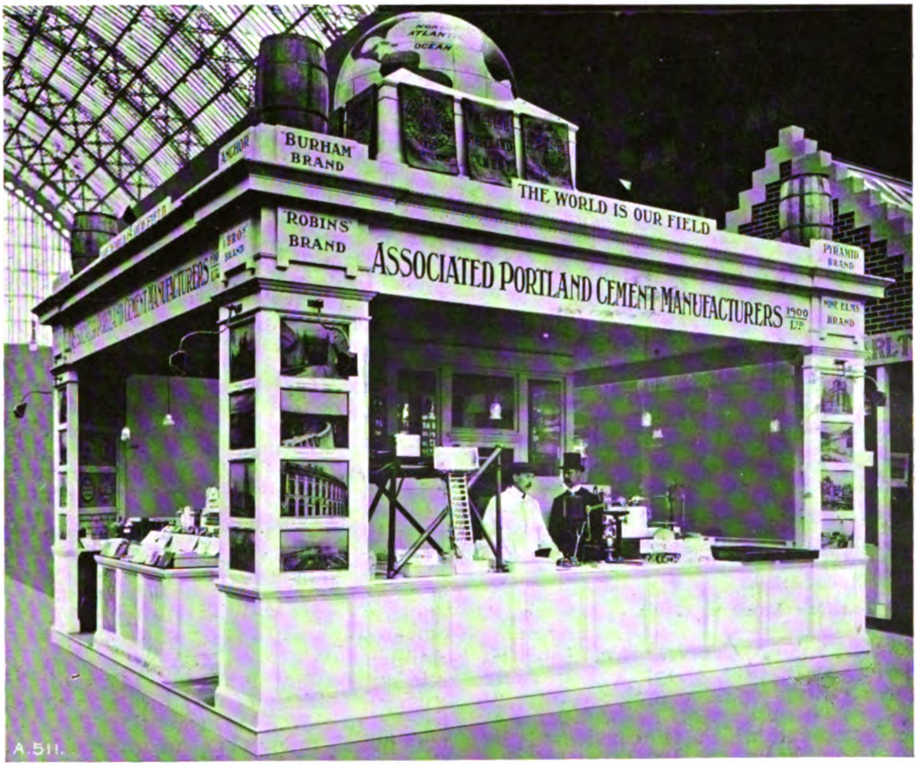
REINFORCED CONCRETE FLOORS.

We now turn to the stands where reinforced concrete was represented, and at the outset we cannot help saying that the attention devoted to this department of building construction was somewhat disappointing. In making this remark it must be clearly understood that we are not referring to the various praiseworthy exhibits of the firms who were represented at the exhibition, but to the firms who have not thought it necessary to put in an appearance. An occasion like that afforded by the Building Trades' Exhibition is, in our opinion, one that ought to be seized upon by reinforced concrete patentees and engineers to bring before British architects the merits of their systems, more especially as numerous members of the profession make it a practice to avail themselves of the opportunity offered for studying the different materials and methods of construction so conveniently brought together by exhibitors. The absentees this year included not only some of the leading reinforced concrete firms, but many others who make a speciality of concrete and reinforced concrete fire-resisting floors, roofs and structural details wherein reinforced concrete is employed wholly or in part. There is, however, a counterbalancing feature to be found in the fact that several firms hitherto scarcely known in connection with reinforced concrete are beginning to apply the material to sundry details, thus suggesting that the valuable qualities of reinforced construction are becoming generally recognised by the building trades. This in itself is a distinctly hopeful sign of progress.

One of the best exhibits at Olympia was that of the *New Expanded Metal Co.*, which occupied a special position in row E with a structure embodying examples of columns, floors, suspended ceilings partitions, walls, roofing, and casing for steelwork. Expanded steel is so admirably adapted for reinforced concrete construction generally that we cannot help regretting that the company should continue to pin their faith to rolled steel joists in column and beam construction. Heavy rolled sections are invaluable in their way, but need not be used in conjunction with concrete, for the reinforcement of which bars of smaller section are infinitely better. As to fire-resistance, floors by this firm have been twice successfully tested by the British Fire Prevention Committee, the second test resulting in the highest classifiction of fire-resistance obtainable.

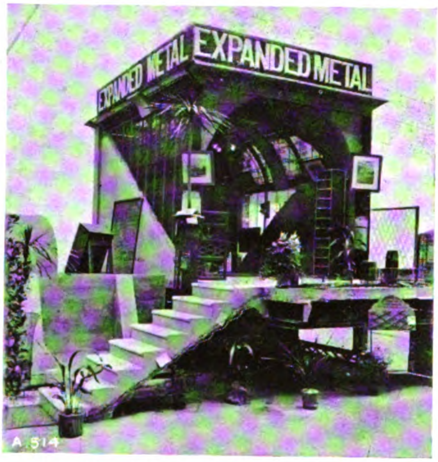
The Columbian Fireproofing Co. Ltd. (row C, special position No. 9) were represented by a very cleverly designed structure showing methods of Columbian reinforced concrete floor and roof construction. The floor, built between rolled steel joists, spaced 16 ft. apart, was of the panelled type reinforced by 3½ in. Columbian bars suspended by steel saddles from the top flanges of the joists and embedded in a 6-in. slab of concrete. The stand was covered by a mansard roof with a central dome and dormers at the sides, the basis of the whole being a framework of Columbian bars, which are covered by concrete. From the fire point of view, the Columbian floors were the pioneer concrete floors according to modern requirements, and obtained a high classification under the Fire Prevention Committee's tests as far back as 1899. Examples of "Bonna" reinforced cement pipes were to be found in the same exhibit and various samples of bars and materials used by the company in their ingenious and economical methods of construction.

The Patent Indented Steel Bar Co., Ltd. (row Q, No. 228) had a neatly-arranged exhibit, including some de-



STAND OF THE ASSOCIATED PORTLAND CEMENT MANUFACTURERS (1900) LTD.

lightful models of a retaining wall, floor. column, sewer, culvert, tunnel, and bridge construction, in which the concrete is reinforced throughout by steel bars of special section with the object of affording an absolutely secure mechanical bond, in addition to the cohesion between the concrete and the metal. The bars are of high-carbon steel, with an ultimate resistance far beyond that of the mild steel bars generally favoured in this country and on the Continent, but we understand that mild steel bars of identical section can also be obtained from this firm if desired. Part of a concrete slab was shown taken from a floor recently tested by the Fire Prevention Committee in which the highest classification obtainable was accorded. The slab is still in excellent condition.



THE NEW EXPANDED METAL CO.'S STAND

The Trussed Concrete Co. (row H, special position No. 13) had a stand where visitors could examine specimens of the Kahn bar in all sizes, a form of reinforcement which is considered by many engineers to be very suitable for the design of beams and floors. The rigidity and mono-metallic connection of the shear members with the main portion of the bar are features whose desirability must not be overlooked, and there can be no doubt that when these bars are properly applied in horizontal work and embedded in well tamped concrete, the result is satisfactory. On the stand the visitor also found some specimens of beam, slab, and column construction.

Messrs. Richard Johnson, Clapham & Morris, Ltd., of Manchester (row D, No. 83) exhibited walls, columns, floors, roof slabs, and stairs built in accordance with Johnson's wire-lattice system of reinforced concrete, Johnson's system of encasing structural steelwork, and reinforced plaster partition construction.

Messrs. D. G. Somerville & Co. (row E, No. 24) showed a steel frame constituting a reduced facsimile of the upper part of the steel-framed building erected at Paddington for the National Telephone Co. This structure included reinforced concrete slab floors and roof slabs.

Messrs. Somerville also showed sections of *Poole's* patent reinforced concrete piles as now being applied to the reconstruction of the Town Quay, Southampton, and models illustrating Poole's system of protecting timber piles and steelwork. The form of pile to which we now refer is built up of reinforced concrete slabs connected together to form a hollow casing afterwards filled up with concrete. Of course the piles cannot be driven, and consequently are not "piles" according to the correct meaning of the term. But they can be built up from the top of a timber or other pile, and the slabs can be employed for casing timber piles which have been injured by continued exposure. We understand that the necessity for repairing timber piles first suggested the idea of this patent to the inventor.

The Fireproof Company, Ltd. (row A, Special Position No. 14 and Wall Space No. 151), while still adhering to rolled steel sections in floor construction, begin to give indications that genuine reinforced concrete design may ultimately become one of their specialities, and a light lattice girder (or bow-string girder) promises well in this direction. They already make partition slabs reinforced with corrugated steel sheeting, a material which is also applied by them to the construction of partition walls, floors, ceilings and beams, and are makers of reinforced-concrete pipes. One of the earlier partitions of this firm was tested by the British Fire Prevention Committee quite a number of years back. Corrugated sheeting is also applied to the fireproofing (*i.e.*, the encasing) of ordinary steelwork—a most useful purpose.

OTHER FLOORS.

The Kleine Patent Fire-Resisting Flooring Syndicate, Ltd. (row D, No. 82), occupied a building designed for the purpose of representing floor and roof construction in hollow brick, the joints of which are reinforced with flat tension bars bedded in cement mortar, concrete also being generally used as a covering. The floor here exhibited had the clear span of 12 ft., and supported two roof slopes surmounted by a flat slab of reinforced brickwork with the span of 8 ft.

A dormer window projected from one slope, and an opening through the flat part of the roof served to indicate the practicability of making openings of considerable size without the necessity for trimmers. When fully developed and officially tested against fire under British Standard conditions this form of construction will probably rank as a composite reinforced brick and concrete system of considerable possibilities.

STAND OF THE COLUMBIAN FIREPROOFING CO., LTD.

Messrs. Mark Fawcett & Co. (row M, Nos. 191 and 192) showed rolled steel joists between which terra-cotta floor tubes are fitted to represent the preliminary stage of their floor construction. The joists are made in accordance with Fawcett's patent, and have a much smaller flange at the top than at the bottom in recognition of the compressive resistance provided by the concrete filled in above the terra-cotta tubes. The tubes are now made so as to permit the joists to be spaced 30 in. apart instead of 24 in. as formerly, but even with this improvement the panels are extremely narrow as compared with reinforced-concrete floor panels, and necessitate a wasteful employment of metal. Narrow spaced floor work with dense terra-cotta lintels must, however, be looked upon as gradually becoming a system of the past, and their fire-resistance has been frequently strongly criticised both in the United States and at home.

The Acton Concrete Partition Co. (row F, No. 106) exhibited their solid interlocking concrete partition slabs, which are admirable for economy of space.

CONCRETE BLOCKS AND ARTIFICIAL STONES.

The Improved Construction Co., Ltd. (row D, No. 79) showed examples of reinforced concrete railway sleepers, which at present are quite a novelty in this country. The same firm also exhibited a very substantial form of concrete building block for the construction of hollow walls, concrete paving slabs and tiles, concrete steps, copings, and sewer pipes. The company are evidently quite alive to the advantages and universality of concrete as a structural material, but do not appear to recognise the fact that by the adoption of reinforcement to more of their manufactures, the weight and cost of production might be materially reduced without reduction of strength.

The Swansea Stone Block and Machine Co. (wall space No. 233) exhibited a good selection of concrete hollow building blocks, partitions, etc., interesting blocks in different styles, and a handy form of block-moulding machine, whose special advantage is that as the blocks are moulded the machine is removed for making the next block, all the blocks being left until required for use.

The Cavity Ventilating Building Block Syndicate exhibited (Bay No. 2) concrete blocks. The system is such that practically any aggregate can be used in conjunction with Portland cement in the manufacture of building and partition blocks, fire flag and roof tiles and artificial stone for all purposes. The following points should commend its use, ensuring as they do sound-proof, effective cavity walls, with all the advantages of solid construction. The evenness in temperature which insures coolness in summer and warmth in winter, thorough ventilation, and the rapidity with which the buildings can be erected.

Messrs. Sutcliffe, Speakman & Co., Ltd. (bay No. 2) displayed reinforced concrete paving slabs, concrete bricks, lime sand bricks, clinker bricks, plain and coloured concrete tiles in great variety, and also had on view a large press for moulding concrete bricks and building blocks.

The Imperial Stone Co., Ltd., of East Greenwich (Row B, No. 33 Gallery), exemplified various uses of concrete and reinforced concrete in the form of Imperial stone, silicated stone, or silicated stone concrete. Their spaces included examples of paving slabs, steps, cills, window heads, and other goods. The larger sized pipes made by the company are reinforced by steel ribs, and have been made up to 48 in. diameter. Imperial stone is a very close-grained product, much resembling York stone.

The Patent Victoria Stone Co., Ltd. (Row B, No. 21 Gallery), exhibited their well-known artificial stone in various forms. A massive carved porch, made for the Tottenham and Edmonton Gas Co., formed an interesting subject, with its carved capitals, etc., while a considerable amount of attention was shown to a paving slab made of the Company's material. This stone had been taken from London Bridge, where it had laid for fourteen years, showing the least possible signs of wear notwithstanding the enormous traffic during the period. Excellent specimens of a moulded staircase, various vases, pedestals, and finals completed what was undoubtedly a fine exhibit. This firm is responsible for the paving of the whole of the streets at Ilford, and have supplied stone for that district alone for 100 miles of paving during the last twelve years.

Sharp, Jones & Co. (Stand No. 103, Row F), exhibit rock concrete tubes and manholes, with fittings and gullies of Dorset clay. Of these tubes, the outstanding feature is the "Brandram" joint, consisting of a steel band coated with bitumen.

Taking the exhibition as a whole, we find a very fair sprinkling of stands where Portland cement products were in evidence in spite of the indifference to publicity displayed by many well-known firms. At the same time we were struck with the remarkable absence of steel constructional engineers, steel manufacturers, rolling-mill proprietors, and ironfounders. In the classified index to the official catalogue the headings steel and iron are not to be seen, and there was not in any part of the exhibition a single stand devoted to structural steel, steelwork, or structural castings, apart from those where such materials were included in a purely subsidiary manner.

Firms who are engaged in pushing concrete and other refractory building materials have good reason for gratitude to the iron and steel trades for withdrawing their competition in so obliging a way.

Stand of the Patent Indented Steel Bar Co., Ltd.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

A New Bridge.—The City Council of Auckland inform us they have invited tenders for the construction of a road bridge over what is known as the Cemetery Gully, and have called for alternative designs in reinforced concrete and steel, while favouring construction in the former. The length over all is to be 810 ft. from centre to centre of abutments, with a further 100 ft.of solid filling held up by vertical retaining walls. It will consist of five spans, one of 200 ft., two of 175 ft., and two of 130 ft. The height of the roadway above the lowest point of the gully is nearly 140 ft.

* * *

Trade Announcements.—The Local Licensees of the Coignet System, Messrs. Watt Bros., of West Hartlepool, have secured the contract for the extensive Ore Sheds for the Central Zinc Co., Ltd. The general dimensions are 300 ft. long and 46 ft. wide. The structure is calculated to carry three railway lines and heavy engines, and will be entirely in the Coignet system of armoured concrete. Owing to the development of their business, Messrs. Coignet have moved to 20, Victoria Street, where they have taken extensive new offices.

We learn that the Century Cement Machine Co., of Rochester, N.Y., has just shipped six Hercules Block Machines to one contractor in Cairo, Egypt. This is the second order from the same contractor.

* * *

A new Publication.—The Association of American Portland Cement Manufacturers, with the object of meeting the growing demands for reliable information regarding the proper use of Portland cement, have started a four-page pamphlet, in which they intend to print original articles from leading authorities, while making extracts from articles in other publications; and at the same time advise readers where the complete articles may be found. The name of the leaflet is *The Concrete Review*.

* * *

Catalogues.—The new catalogue issued by the Clinton Wire Cloth Co., Clinton, Mass., entitled "Clinton Wire Lath," is an admirable specimen of its kind. The introduction briefly but clearly describes the advantages attained by the use of this lath, and details of specifications for plastering, directions for lathing, plastering, decorative ceiling and cornice work are some of the instructive items dealt with in its pages. The catalogue is profusely illustrated.

We have received from the Ideal Concrete Machinery Co. a booklet, entitled "What Others Say About Us," which contains a rather unique selection of expressions of satisfaction received from their various customers. This was accompanied by one of their catalogues, and a collection of views, which are most interesting.

* * *

Award.—The Patent Indented Steel Bar Co., Ltd., inform us that they have been awarded a Gold Medal by the Jury of Awards of the International Exhibition at Christchurch, New Zealand. This is the third Gold Medal that the "*Indented Bar*" has been awarded at International Exhibitions.

* * *

A Patent Action in Canada.— An interesting decision has been given in the Canadian Courts, where the Ideal Concrete Machinery Company, of South Bend, Ind., obtained an injunction against a competitor, who, after opening negotiations for the purchase of rights of manufacture under the Canadian patent, and visiting and thoroughly examining the Company's factory, constructed a similar machine and sought to patent it. After a three days' trial, the Court upheld the plaintiffs' patent and granted the usual injunction.

* * *

A Competition.—The Association of American Portland Cement Manufacturers recently issued a programme of a prize competition for Designs for Suburban Dwellings in Concrete. The designs are divided into two classes—single or detached dwellings and twin or semi-detached dwellings. In both classes the use of cement and concrete is desired, wherever practicable.

* * *

A correspondent informs us that when H.R.H. the Prince of Wales visited the Building Trades' Exhibition, he displayed considerable interest in a test which was being carried out at the stall of the Associated Portland Cement Manufacturers (1900), Ltd., and also greatly admired the splendid collection of photographs of works in which their various brands have been used.

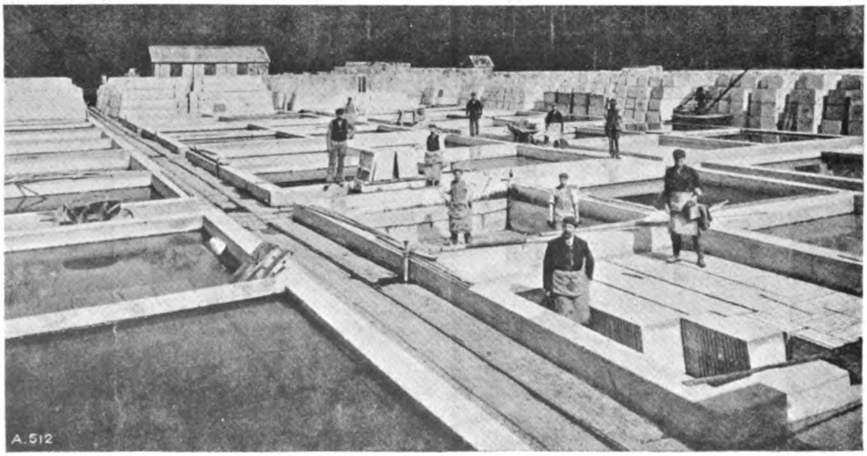
* * *

Corrections.— We desire to publish the following corrections of errors which appeared in our article on Artificial Stones in the previous number :—

Beaconstone.—The description given applied only to Architectural Dressings, and not to paving or staircase work, which is composed of specially prepared granite chippings and fine cement.

Victoria Stone.—The manufacturers of this stone state they have one of the largest tanking grounds, enabling them to tank half-a-million feet at one time. The statement that this stone was *not* tanked directly it is made was erroneous.

We have pleasure in reproducing a photograph of the Company's tanking ground at their Groby Works, which gives a good idea of its extent.



THE INDURATING TANKS AT THE GROBY WORKS OF THE PATENT VICTORIA STONE CO., LTD.
(Capacity half-a-million super ft. of 2-in. paving slabs.)

CORRESPONDENCE.

"CONTINENTAL METHODS OF CALCULATION"

As put forward by Monsieur DE TEDESCO.

SIR,—In bringing forward some questions arising out of the article by M. de Tedesco in your March issue, I wish at the outset to express full appreciation of the difficulty, which has evidently been felt by the author, involved in any attempt to deal satisfactorily with a very wide and complicated subject within the narrow limits of a single short article. This circumstance is no doubt responsible for the somewhat fragmentary nature of the contribution to which I refer, and the fact that the author has written in English may, in spite of his admirable command of our language, account in a measure for some of the ambiguities mentioned in your editorial introduction.

Recognising the authority carried by M. de Tedesco's name and the importance of the subject discussed by him, my position is that of one desiring the elucidation of points that appear obscure, my hope being that the author will give such further explanation as may help your readers to follow more readily the analytical treatment of the three methods of calculation considered in his interesting article. I say three methods, because the two others mentioned are not discussed fully. One of them, "Edmond Coignet's Old Method," is presumably obsolete, and the other, "Professor Ritter's Method," is only accorded very brief notice. The systems of calculation remaining are those of M. Hennebique and the author, both empirical, and that of M. Considère, which comes under the category of "Rational Methods."

Most engineers will agree with the view that rational methods of computation are to be preferred to empirical formulæ, although the latter have been applied with perfect safety for many years past, and are still used by various eminent designers, including M. de Tedesco himself, as stated on page 54. While deprecating the use of such formulæ, the author in the concluding paragraph, on page 57, appears to recommend them for practical work in preference to rational methods, for the reason that the latter are neither handy nor expeditious. Judging simply by the two empirical methods side by side with the one rational method as expounded in the article, I think most people would agree with this conclusion. But there are other and much more convenient rational methods than that of M. Considère, who does not seem to have made any attempt, like some authorities who have propounded rational methods, to evolve simplified working formulæ for every-day use.

M. de Tedesco refers in his opening remarks to the desirability of a standard method of computation, and of handy transformations of the same for practical men. With these suggestions I am in entire accord, and their perusal raised the hope that the author was about to set forth some helpful formulæ of the kind that could be used in daily work. This hope proved to be vain, but it is possible that you may be able to induce M. de Tedesco to present in some future issue of your valuable journal a compact and systematic series of such rules for the guidance of designers. In the meantime we must accept the article as a review of three French methods of calculation, which deserve careful study.

I have gone through the demonstrations and calculated examples presented by the author, and believe that I have correctly understood his line of reasoning, notwithstanding the ambiguities already mentioned. It is possible, however, that some of your readers may not have sufficient time at disposal for the unravelment of tangles, and that others who are in the position of students may be confused by discrepancies and obscurities. Therefore, at the risk of being thought inappreciative, which I assure you and my honoured French colleague is far from being the case, I enclose a series of notes upon various errata and expressions which at least are open to misconstruction, and thus are likely to detract from the practical utility of the demonstrations submitted by your talented contributor.

I am, sir, your obedient servant,

QUAESITOR.

Page 53.

Col. 1, line 12.—After the words "Hennebique writes: $P=344C+13760R$," it would be well to add "Where 344 = unit compressive stress in the concrete, and 13760 = unit compressive stress in the reinforcement."

Line 30.—For "6·23 sq. in." read "6·28 sq. in."

Line 31.—"Let us say 6 bars $\frac{5}{8}$ in. diameter giving 6·24 sq. in. area." This is a clerical error, for the area of six such bars is only 6×0·3068=1·8408 sq. in. The nearest standard diameter to that necessary is 1$\frac{3}{16}$ in. giving the area of 6×1·1075=6·6450 sq. in.

Col. 2, line 13.—"Weight of the concrete (3×13 lb.)" would be clearer if it were stated that 13 lb. is the weight assumed per sq. ft. of reinforced concrete 1 in. thick. It would be better still to substitute for "3×13 lb.)" the rate "at 156 lb. per cub. ft."

Line 23.—For "196 sq. in." read "0·196 sq. in."

Page 54.

Col. 1, line 5.—In the denominator of the expression for H_1, the value of ·5 is printed instead of 5.

Line 28.—After "$M=\frac{pl^2}{8}$" should be added, for the convenience of readers, "where p=total load in pounds per sq. ft., and l=clear span of the slab in feet."

Line 31.—After "497·5" add "foot-pounds."

Line 32.—After "2·70" add "inches."

Lines 38 to 43.—The height of the rib of a T-shaped beam with single reinforcement may often be "approximately the same" as the other height mentioned in this paragraph, but the author surely cannot wish to suggest that the two dimensions are always equal. When explaining this perhaps the author would kindly say how he measures the height of the T-beam rib. That is to say, whether he takes measurements between the bottom surface of the concrete and the under side of the slab, or between the axis of reinforcement and the top surface of the slab, or between any other points.

Lines 23 to 43.—Referring generally to M. de Tedesco's empirical formulæ, it would be interesting to know the derivation and signification of the constants 0·12, 12, 200, and 1300. Without information of the kind, the reader is quite in the dark and is unable to realise the theory underlying these equations, or to compare them with rules of similar character.

Page 55.

Examining *Figs.* 3 and 4 in connection with the table of notation below them, several points are found which suggest comment, and require explanation.

(1) A matter of minor importance is that the tick appended to various symbols is not applied in accordance with any system. In three cases the tick indicates the compression side and in five cases the tension side of the beam. It is inevitable that a large number of symbols of more or less unfamiliar character must be employed in reinforced concrete formulæ. In itself this necessity involves a considerable strain upon the memory and patience of the user, whose sufferings are exaggerated by haphazard nomenclature. To take the case now in point, it would be far more easy to follow the demonstration of M. Considère's theory if the reader knew that a tick after any given symbol always denoted either compression or tension instead of sometimes one and sometimes the other.

(2) In *Fig.* 4, the symbol R''_c appears to indicate unit stress of the reinforcement in tension, but this symbol is not to be found in the table of notation, where, however, the stress in question is represented by the symbol R_s.

(3) In *Fig.* 4, the symbol R_c is written where it corresponds with maximum unit stress of the concrete in tension, but in the table of notation this stress is denoted by the symbol R_t. There is clearly an error, because a second symbol R_c in *Fig.* 4 is correctly used to indicate maximum unit stress of the concrete in compression.

(4) In *Fig.* 4, the symbol $R^{\bullet}_c$ occurs along the centre of the reinforcement in compression, although not to be found in the table of notation, where the corresponding stress is denoted by the symbol R_s'. As the axis of compression in the concrete may be coincident, or nearly coincident, with the axis of compression in the reinforcement, and as the affix *c* is generally used by the author in connection with stresses in concrete, it is not improbable that $R^{\bullet}_c$ may have been written in error for R'_c which in the table of notation stands for unit stress in the concrete at the distance *u'* from ABCD. It should be noted, however, that although the author gives this symbol in the table of notation he does not make use of it anywhere in his subsequent demonstration.

(5) In *Fig.* 4 the author employs the letter *l* to denote *breadth,* instead of *b*, as on p. 53. This is an unnecessary variation whose inconvenience is augmented by the use on p. 54 of *l* to indicate *length*. Further, in *Fig.* 4, *l* is applied to the width of the flanges both in compression and in tension, while in the table of notation a distinction is drawn but not defined between *l* and *l'*. This ambiguity can be cleared up by inference after consideration of the equivalents of λ and λ'

(All the foregoing discrepancies suggest that the author does not completely realise the practical advantages of standardised methods of nomenclature whose theoretical desirability he urges on p. 52.)

Page 56.

In reading this page the writer did not at first recognise the meaning of the numerals at the beginning of the various paragraphs. He discovered afterwards that they refer to stress areas similarly numbered in *Fig.* 4, and to the corresponding arms of leverage. By the insertion of a few words the author could have made this matter perfectly clear.

Col. 1, par. (*1*).—Instead of "compressive strength $= \frac{aR_c}{2}(h-x)$" the author should write "*total compression*" as the first term of the equation, because the second term expresses the product of mean unit stress into the stress area.

Col. 1, par. (*2*).—"*Compression slab* Breadth$=\lambda$". By *Fig.* 4, $l=$the collective width of the slab and rib, and $\lambda = (l-a)$, while by the table of notation $\lambda=$the ratio $\frac{l-a}{a}$. These two definitions are contradictory and make it very difficult for the average reader to discover what the author really means. If λ is a ratio it cannot possibly be a definite linear measurement.

Again, "Average unit stress see trapezium ABKR $= \frac{R_c + R'_c}{2}$." Presumably the author means by the "trapezium ABKR" the *trapezoid* ABR_c' in the stress diagram of *Fig.* 4, having omitted to write in the letters KR. But the author uses no symbol to denote average unit stress and gives none in his table of notation.

In the succeeding sentence the symbol λ occurs twice, and the reader ought to be informed as to which of the two different significations he is here to accept, and after the word "whence" the author should have inserted "total compression=" if he wished to be quite lucid. The second term of the equation contains the symbol "ϵ," which is evidently a printer's error, and presumably should be "*e*."

Col. 1, par. (*3*).—Further confusion arises in this paragraph by the introduction of Rc' a symbol neither in *Fig.* 4 nor in the table of notation. If the author meant R_e' to be read there would still be something wrong, for although the stress R_e' as defined may happen to be the mean unit stress, this is not necessarily the case, because the axis of compression in the reinforcement can be fixed arbitrarily, while the axis of compression in the concrete is governed by the laws of geometry.

After the word "Then," near the end of this paragraph, should be inserted "total compression=".

Col. 1, par. (*4*).—After the word "Then," near the end of this paragraph, should be inserted "total tension=".

Col. 2, par. (*4bis*).—After the word "Then," near the end of this paragraph, should be inserted "total tension=".

Col. 2, par. (*5*).—"Breadth$=\lambda'$" (see previous note on this subject). After the word "Then," near the end of this paragraph, should be inserted "total tension=".

Col. 2, par. (*6*).—After the word "Then," near the end of this paragraph, should be inserted "total tension=".

Col. 2, par. (*2*).—"See the centre of gravity O of the trapezium ABA'B'." Perhaps the author will be kind enough to explain where this trapezium is to be seen. The only place where the letters ABA'B' are to be found is *Fig.* 3, where they do not indicate a trapezium.

Page 57.

Col. 1, lines 30 to 36.—Calculations (1), (2), and (3) are incorrect, because by a clerical error the value of $f=\cdot0147$ has been used instead of $f=\cdot0157$, as calculated in line 29.

Col. 1, line 40.—See previous note relative to contradictory definitions of λ.

Col. 2, line 2.—Ditto.

Col. 2, line 9.—Here we have a third value for λ, now stated to be equal to $\frac{l}{a}$. Thus by *Fig.* 4, $\lambda\ l-a$; by table of notation $\lambda = \frac{l-a}{a}$; and by p. 57, col. 2, line 9, $\lambda = \frac{l}{a}$; which is anomalous and, according to Euclid, "absurd." But a further puzzle is provided for the reader by the suggestion that λ is also equal to $\frac{16-a}{a}$. At first sight it looks as if $16=l$, in compliance with $\lambda = \frac{l-a}{a}$. This cannot be the case, because on referring back to Example 2, cited on line 4, we find that the value of l, there termed b, is 5 ft., whereas the factor employed by the author is 16. If this value has been used in error then all the succeeding calculations are wrong, and on the other hand if, as appears probable from the context, it represents the value of H, we have a fourth signification, or $\lambda = \frac{H-a}{a}$, or $\frac{h-a}{a}$ by the author's table of notation for the Considère formulæ.

If "rational" equations were usually treated in the manner here exemplified there would be much reason for concurrence with the concluding remark of M. de Tedesco that they are "by no means handy for ordinary calculations or for the expeditious design of reinforced concrete buildings."

A reply by Monsieur de Tedesco will be published in our next issue.—ED.

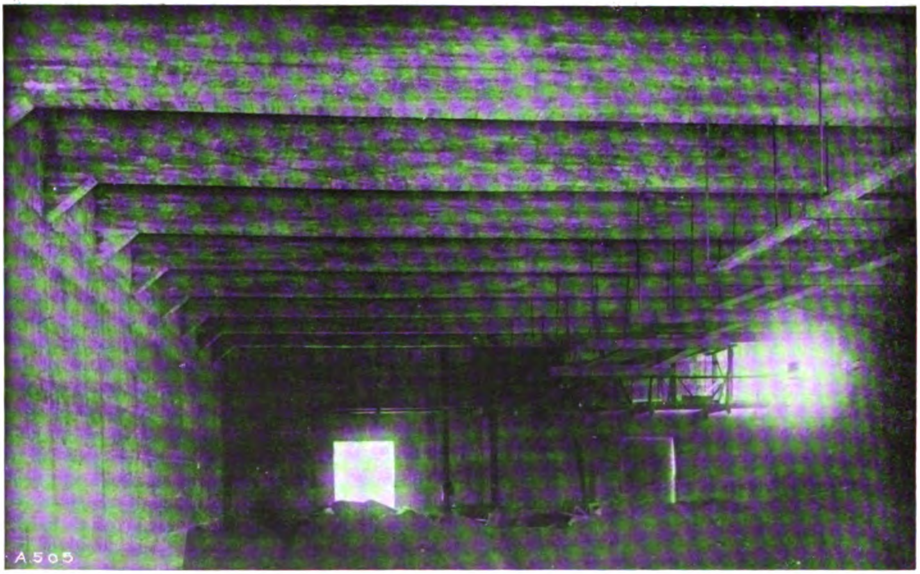
NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course or construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

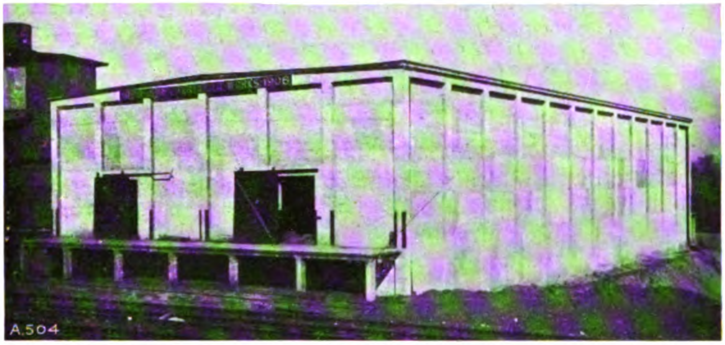
THE TANKAGE BUILDING OF THE SWIFT FERTILIZER WORKS, ATLANTA.

A REINFORCED concrete building, 60 ft. by 120 ft. in plan and about 50 ft. high from the floor surface to the bottom of the roof girders, consisting simply of four enclosing walls and a roof, has been built at the Swift Fertilizer Works, Atlanta, Ga., for the storage of a by-product of the stock yards, called "tankage," which is shipped in bulk and is the base of some commercial fertilizers. As this material was to be handled by overhead conveyors and belt elevators it was desirable that the building should be built as a shell, without intermediate floors or interior columns. In addition to meeting these conditions it was also necessary to design the walls to resist the pressure of a fill of loose earth, the surface of which at the walls is 26 ft. above the floor level.



CONCRETE BEAMS 53 FT. CLEAR SPAN.

The end and side walls are alike in design. Below the surface of the fill the walls are 12 in. thick and are divided into sections by counterforts placed 10 ft. centre to centre. The steel reinforcement is proportioned according to the depth of the fill, as is shown in the accompanying general cross-section of the building. At about the level of the top of the fill a water table extends around the building and above this the walls are only 9 in. thick. Here, reinforced pilasters 16 in. wide and 8 in. thick, placed 10 ft. centre to centre and directly above the counterforts, give additional strength. The wall footings are reinforced and extend outward 7ft. to the outer line of the counterforts and inward 7 ft. under the floor, both measurements being made from the centre of the 12 in. wall. These footings are in general 1 ft. 8 in. thick, and are reinforced in both the top and bottom surfaces. They are designed to take advantage of the weight of the earth fill in resisting the overturning moment due to the lateral pressure of the earth. In the walls and footings 1 : 3 : 6 concrete was used, and new style Johnson bars of high carbon steel were used throughout the structure.



COMPLETED TANKAGE BUILDING.

The floor is of plain concrete mixed in the proportion 1 : 4 : 8, 5 in. thick, and laid on a bed of cinders 8 in. deep. Over the surface of the concrete was laid one layer of roofing felt. This was mopped twice with roofing pitch, and a top finish of 1 in. of cement was then applied. The outside of the walls was also mopped with roofing pitch below the water table. Three longitudinal lines of 4-in. terra-cotta pipe, laid with open joints in crushed stone, under the floor, and a similar line just outside the counterforts on each side of the building, drain the foundation soil.

The roof has a pitch of ¼ in. in 1 ft. from its longitudinal centre line, and consists of 4 in. of reinforced concrete covered with three-ply tar and gravel roofing. It is supported on 1 : 2 : 4 reinforced concrete girders, 13½ in. thick, 4 ft. 2 in. deep at the centre, including the thickness of roof, and having a clear span of 58 ft. from inside to inside of the side walls.

These girders are spaced 10 ft. centre to centre. In the lower portion of each girder are seven 1 in. and four ½ in. bars, and at each end are ½-in. shear bars. A longitudinal girder, 6 in. by 18 in. in section, not including the thickness of the roof, is placed immediately under the ridge of the roof, and connects the main girders. It is reinforced with one 1 in. bar in its lower surface.

In building the walls the forms of the counterforts and pilasters were built in position and securely braced to act as guides for movable forms which were used for all curtain walls between the pilasters and counterforts. These movable forms were built in sections 32 in. high, each section consisting of two 3 in. by 4 in. stringers, to which ⅞-in. matched flooring was nailed. Two sets of these forms were provided for each bay, and were alternately removed and replaced above each other. Ordinarily the concrete was allowed two days' set before the forms were removed.

The building was designed and built by the Southern States Reinforced Co., of Atlanta, Ga., of which Mr. George B. Hinman is president, and Mr. A. Francis Walker is engineer. Johnson's corrugated bars (known as "Indented" bars) were used throughout the structure.

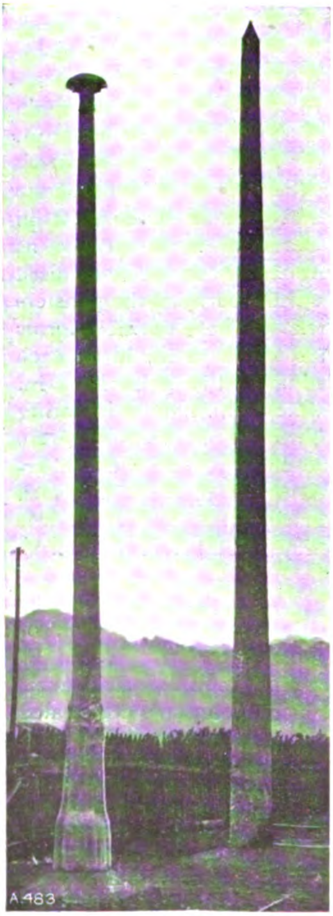
NEW USES FOR CONCRETE

AT HOME AND ABROAD.

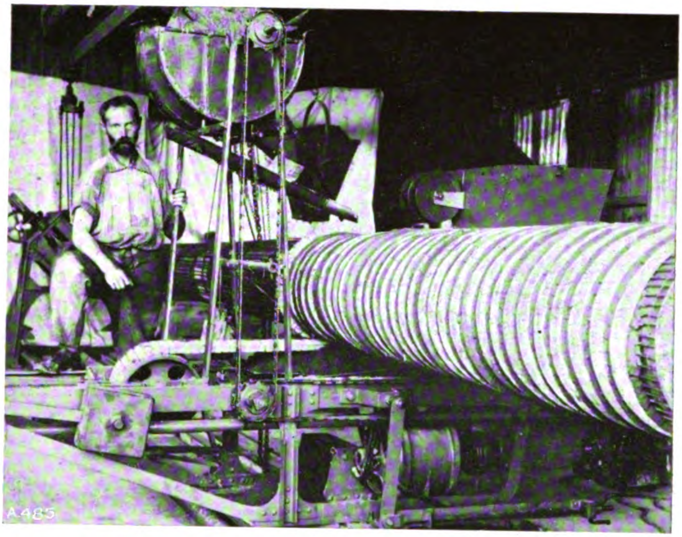
Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

THE SIEGWART CEMENT MAST.

An important and costly element in the distribution of electrical power is the mast or pole used to carry the wires. Wooden poles, most commonly employed, suffer from a lack of durability, owing to their liability to be attacked by rot. Arrangements for protecting them from the action of moisture are often employed, but do not overcome the difficulty. Steel masts, whether of tubular or lattice pattern, are free from this objection, but their initial cost is heavy, and the cost of periodical painting to protect against rust is also considerable. Attempts have been made to employ reinforced concrete masts made by hand, but the weight of such solid masts has to be so considerable to afford sufficient strength that the cost of transport, especially in mountainous districts, becomes great, and even prohibitive.



Herr H. Siegwart, of Lucerne, the inventor of the Siegwart beam, has now designed a type of reinforced cement mast which is prepared entirely by machinery. The mast is a hollow tube, with walls from 2·5 to 5 cm. in thickness, and it may be made to taper to any extent, or given any desired amount of entasis. The reinforcement consists of longitudinal round iron, or steel rods, bound together by continuous spirals of wire. A mixture of coarse sand and Portland cement is used for the construction of the walls. A special machine has been designed for the construction of the masts. The cement mixture is fed by means of an automatically regulated hopper on to an endless band, which applies it to the metal skeleton under a constant pressure. The mixture is thus spread on the skeleton in the form of a spiral band of constant thickness. The inner core is formed by a conical steel tube, slit longitudinally and kept at a constant distance from the reinforcement. This core is withdrawn when the mast is completed. The machine is electrically driven, and all the movements are regulated by means of adjustable gearing. The spiral band of mortar at first deposited by the belt is rectangular in section, but as the belt is followed up by a former, this section is deformed, becoming lozenge-shaped, so that each turn of the spiral is intimately united with the next. At the same time an external reinforcement is applied in the form of a spiral wire. The mast is then wound spirally with textile material,



in order to preserve the original conditions of moisture during setting. A pressure roller is then passed along the mast, consolidating the mass. The finished mast has the form of a tube, smooth inside and out. For the purposes of tramway poles in towns, etc., a cement socket of suitable design may be moulded on.

In a test in which a mast 7.25 metres long (25ft. 6in) was clamped at one end and a transverse pull applied at the other, fracture occurred at a load of 1,300 kg., giving a factor of safety of 5.5.

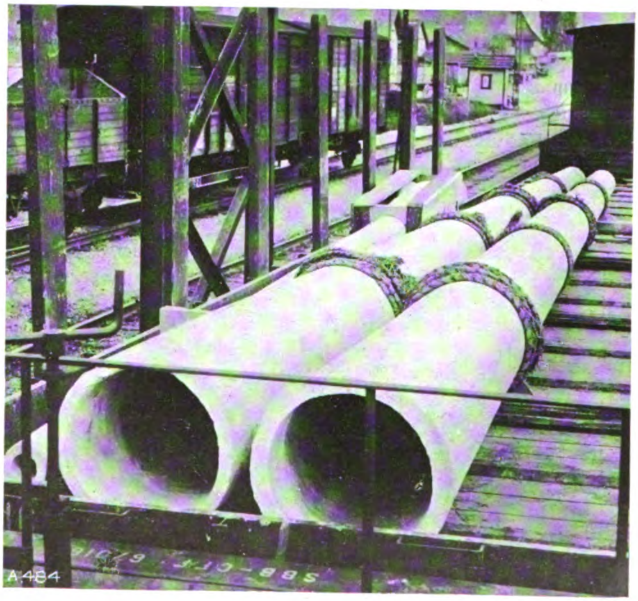
A CONCRETE GREENHOUSE.

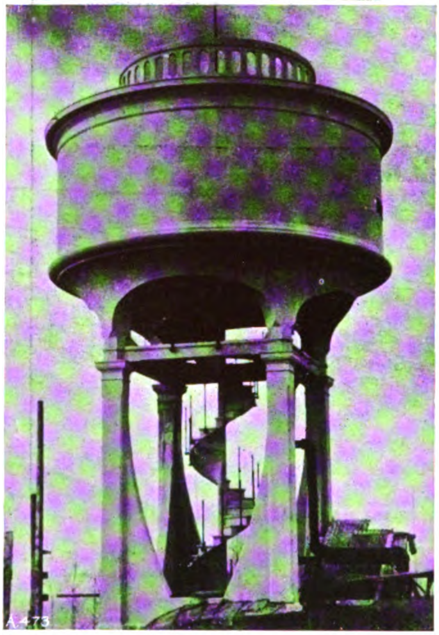
The concrete greenhouse is not only entirely practical, but means the elimination of costs for repairs, and a material reduction in expenses for fuel. Very fine concrete greenhouses have been built at the Soldiers' Home, Washington, and at Westwood, N.J. A method of construction recommended by good authorities is as follows:—

Make the foundation 10 in. broad and below frost, composed of 1 part cement, 3 parts clean, coarse sand, and 6 parts broken stone. On the foundation and at equal distance from either edge erect a wall 7 in. thick and of 1 part cement, 2 parts clean, coarse sand, and 5 parts cinders, to the height required for the wall.

A ridge pole can be erected 6 in. wide, by 8 in. deep, of concrete, consisting of 1 part cement, 2½ parts clean, coarse sand, and 5 parts broken stone or gravel, not over ¾ in. in size. The ridge pole should be reinforced with two steel bars, each 5 in., extended from ridge pole to side wall. Reinforcement with ½ in. bar will be sufficiently strong to support the sashes. Reinforced concrete posts, 8 in. square, should be placed at intervals of 10 ft., to support the ridge pole.

Concrete tables 2½ in. thick, of 1 part cement, 2½ parts clean, coarse sand, and





RESERVOIR AT SCAFETI (ITALY).

5 parts cinders, reinforced with a woven wire fabric, can be built and supported with 4 in. posts of the same concrete. All concrete should have a coating ½ in. thick of 1 part cement and 1 part clean sand. This should be put on after the surface to be covered has been picked with a stone axe, and made thoroughly wet. We would advise, however, in case you undertake this work, that you consult an engineer, architect, or builder who has had experience in concrete construction. It is important that your mixture and placing of the concrete together with reinforcement should be properly done.

A REINFORCED CONCRETE WATER RESERVOIR AT SCAFETI, SALERNO (ITALY).

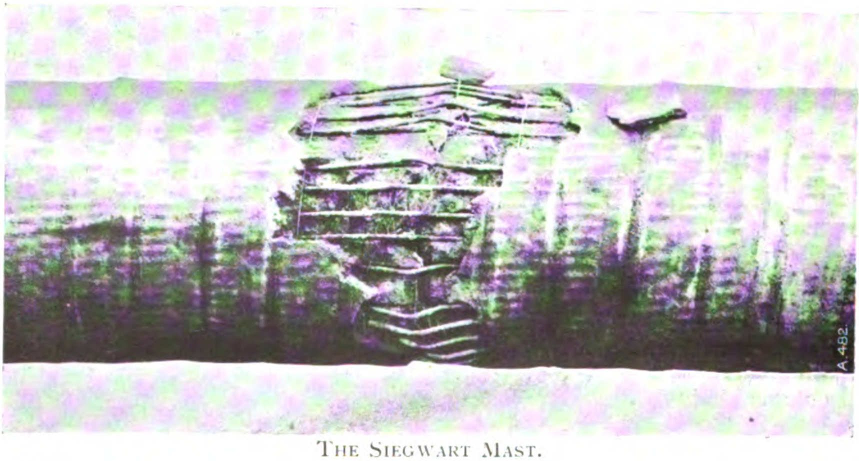
This tank, of which we publish an illustration, has been erected on the Hennebique system for Messrs. Robert Wenner and Co., for the purpose of feeding their Grinnell Sprinkler Equipment at their mill near Naples. We have to thank Messrs. Mather and Platt, Ltd., of Queen Anne's Chambers, for this photograph.

It may also interest our readers to know that there exist at the present moment in Italy many elevated tanks for various purposes, and that there are several installations in different parts of that country, which have as their primary water supply one of these tanks.

The one here reproduced has a capacity of 20,000 gallons.

CONCRETE FOR SHIP REPAIRING.

Concrete has now been successfully used in the United States to repair a hole in the hull of a sunken steamer. The vessel struck on a rock, which stove in the iron hull, the principal break measuring about 35ft. in each direction, the rock projecting into the gap for about 11ft. Heavy canvas was placed over the rock, and concrete over the canvas, after which the vessel was successfully floated and towed into dock.



THE SIEGWART MAST.

NEW BOOKS

AT HOME AND ABROAD.

"A short summary of some of the leading books which have appeared during the past year."

SOME ENGLISH AND AMERICAN BOOKS.

Portland Cement: Its Composition, Raw Materials, Manufacture, Testing and Analysis. By Richard K. Meade, *B.S., Chemist to the Dexter Portland Cement Company, Editor of "The Chemical Engineer," Author of The Chemists' Pocket Manual, &c.*

Published by The Chemical Publishing Company, Easton, Pa., U.S.A., 1906.

Contents: History of the Development of the American Portland Cement Industry.—Chemical Composition of Portland Cement.—The Manufacture of Portland Cement: the Raw Materials, their Proportioning, Preparation, Burning, and Grinding.—Analytical Methods of Examining Cement, Slurry and Raw Materials.—Physical Testing of Cement: Taking of Samples, Testing for Specific Gravity, Fineness, Time of Setting, Tensile Strength, Soundness.—The Detection of Adulteration.

Cements, Limes and Plasters: their Materials, Manufacture and Properties. By Edwin C. Eckel, *C.E., Associate American Society of Engineers; Member Society of Chemical Intry: Assistant Geologist, U.S. Geological Survey.*

Published by John Wiley & Sons, New York; Chapman & Hall, Limited, London, 1905.

Contents: Classification and Relationships of Cementing Materials.—Gypsum and the Plasters derived therefrom.—Limestones and the Limes obtained by Burning. — Lime-sand Bricks.—Magnesia and Oxychloride Cements.—Hydraulic Limes, Selenitic Limes, and Grappier Cements.—Natural Cements.—Portland Cement.—Puzzolan Cements.

Cement and Concrete. By Louis Carlton Sabin, *B.S., C.E., Assistant Engineer, Engineer Department, U.S. Army; Member of the American Society of Civil Engineers.*

Published by Archibald Constable & Co., Ltd., and Dawson & Son, 1905.

Contents: Classification and Manufacture of Cement. — Properties of Cement and the Methods of Testing.—The Preparation and Properties of Mortar and Concrete.—The Use of Mortar and Concrete.

These three works give us an admirable view of the manufacture and use of cementitious material for engineering and building works as seen from an American standpoint, and although, to some extent, traversing similar ground each has its particular differentiating characteristics.

Mr. Meade may be said to deal with the subject of Portland cement considered as a manufacture, and treats in detail of the various materials employed, their value and their effect upon the finished product, the influence of difference of treatment in the preparation of material, the proportioning of ingredients, the burning, cooling and grinding of the clinker, the storage and packing of the marketable cement. The author deals very fully with the laboratory methods of a cement factory, the tests and the apparatus employed for the chemical analysis of the raw material, the mixtures or slurry and the completed cement. The various methods for physical testing of the properties of Portland cement are also fully described and the effect noted of various factors as influencing the behaviour under test and the economical value of the cement. It is interesting to compare the difference in many respects between the standard specifications recognised in the States and our own British standard, thus, whilst our standard forbids the use of more than 2 per cent. of anhydrous calcium sulphate, the Americans allow not more than 3 per cent. and Mr. Meade states that it is *always* added, whereas our British standard specification allows the consumer to prohibit its use in writing. Again, whilst our standard permits 2·5 per cent of sulphuric anhydride the Americans forbid the presence of more than 1·75 per cent. and in a series of analyses made by Mr. Meade on thirteen samples of American cement only one exceeded 1·59 per cent. It is interesting to note that in the two examples of English cements whose analysis is given by Mr. Meade the percentage of sulphuric anhydride is respectively ·96 and ·97. The amount allowed by our British standard specification is undoubtedly a serious deterrent to the use of Portland cement in building with our native limestones. In conclusion we may say that the thoroughness with which the laboratory work of Portland cement making is treated by Mr. Meade renders this book invaluable to the manufacturer.

Mr. Eckel's work is also eminently useful to the manufacturer of Portland cement, as, although the author does not deal so fully with the analytical work of the laboratory as does Mr. Meade, he goes more deeply into what we may term the economical side of the factory, the relation of power and output, of cost and production, of various types of machinery and of various methods of drying, burning and grinding. The short chapter on Heat Consumption and Heat Utilization is alone well worth, to a manufacturer, the cost of the book. Mr. Eckel having included in his treatment not only Portland cement, but gypsum, high-calcium, and magnesian limestones, as well as natural cement, the whole range, one may say, of useful calcareous cementitious products, the value of his work has a wider scope, and though the author deals with his subject from an American standpoint, the effect of location and other factors of cost as economic considerations are so well and adequately discussed that even for British readers the book must have its value as an incentive to thoughtful consideration of the elements that make for commercial success or failure. The information given on the comparatively novel subject of sand-lime and magnesia bricks and the place taken by magnesia products in plaster form is particularly valuable.

The third work of the group we have now before us, Mr. Sabin's book on "Cement and Concrete" is rather for the user than the maker of cement. Only so much space is devoted to manufacture as is desirable for a proper comprehension of the best methods of selecting and using cement. A most valuable feature in the book to the engineer or architect is the investigation into the effect of variations in treatment on the tensile and adhesive strength of cement mortars, the effect, for example, of adding slaked lime to Portland cement for the sake of cheapness, of adding Portland cement to lime mortar to improve it, whilst the effects of clay, sawdust and other foreign substances have been examined and tested carefully to the elimination of the rule-of-thumb and traditional knowledge of the "practical" workman. Highly useful also are the test results on the transverse strength of mortar and concrete, and on the adhesion and cohesion of these materials in conjunction with other substances—steel, brick, stone, etc.

Reinforced Concrete Construction. By Albert W. Buel, C.E., *Member American Railway and Maintenance of Way Association, &c.,* ***and*** **Charles S. Hill.**

Published by Archibald Constable & Co., Limited, London, and The Engineering News Publishing Company, New York, 1906.

Contents: Part I. Methods of Calculation for Beams, Columns, Retaining Walls, Dams, Tanks, Conduits, Chimneys and Arches.—Part II. Representative Examples of Foundations, Building Construction, Bridge and Culvert Construction, Conduit Construction, Tank and Reservoir Construction, Retaining Walls, Dams, Chimneys, etc.—Part III. Methods of Construction.

Concrete Factories. Compiled by Robert W. Lesley, *Associate Am.Soc.C.E.*

Published by Bruce & Banning, New York. *(n.d.)*

Contents: Report of the Sub-Committee on Tests of the Joint Committee on Concrete and Reinforced Concrete of the Am.Soc.C.E., Am. Soc. for Testing Materials, Am. Ry. Engineering and Maintenance of Way Ass. and the Assoc. of Am. Portland Cement Manufacturers.—Lines of Investigation of Mortar and Concrete Building Blocks adopted by the United States Advisory Board on Fuel and Structural Materials.—French Rules on Reinforced Concrete.—Walter Mueller on Reinforced Concrete Construction.—E. A. Trego on Concrete in Factory Construction. — Henry H. Quimby, M.Am.Soc.C.E., on A Surface Finish for Concrete.—Short Notes on Value of Concrete as a Structural Material, by Emile G. Perrot, C. A. P. Turner, E. P. Goodrich, J. R. Worcester, Henry H. Quimby, Dean and Main, Leonard C. Wason, E. S. Larned, Chester J. Hogue, J. G. Ellendt, A. E. Lindau.

Concrete Block Manufacture. By Harmon Howard Rice.

Published by John Wiley & Sons, New York, and Chapman & Hall, Limited, London, 1906.

In these three books we have a purview of modern American practice in various methods of using concrete. Messrs. Buel and Hill's book is now in its second edition, revised and enlarged, a proof that the earlier edition has been appreciated and recognised as a standard work and that the advance in our knowledge of all that pertains to reinforced concrete has been noted and utilised by the authors. We are in complete agreement with Mr. Buel's admission in his preface that "it is questionable whether an entirely satisfactory treatise on flexure in reinforced concrete can be written until more experimental data are available." Indeed we might extend the criticism to the whole subject of reinforced concrete and say that we are yet far from any satisfactory standardisation of either theory or practice. Such works as this by Messrs. Buel and Hill are most valuable in epitomising the knowledge and experience already achieved and in marking time for the advance of further investigators and experimenters. Although there are included some few instances of European work the examples quoted are chiefly those of American construction, and, speaking generally, we might say that European efforts at progress are ignored.

Mr. Lesley's compilation only comprises articles and papers presented in our contemporary, the *Cement Age*, and as such is a useful summary of recent writings.

Mr. Rice's work explains the methods, the capabilities and the limitations of concrete-block building of hollow walls, an American method that has met with much success in the States, but for which the building by-laws of this country are not yet ready, and would rather spell trouble for the pioneers here of the industry.

Constructional Steelwork. By A. W. Farnsworth, *A.M.Inst.M.E.*

Published by Charles Griffin & Company, Limited. London, 1905.

Contents: Practical Designing.—Practical Shop Work.

This is a most useful work for those who design and for those who have to carry out work in mild steel. The designer has pointed out to him what he does not learn from mathematical text books, the practical working considerations that make for cheapness with efficiency, or for extravagance without compensating advantages. Absolutely necessary knowledge for the young engineer or architect who proposes to design modern iron construction with the most advantageous expenditure of his client's money is to be found in the pages of this book and may be more quickly learnt therefrom than by actual experience in drawing office, counting house and workshop.

Notes on Construction in Mild Steel. By Henry Fidler, M.I.C.E., *Author of the article on "Dockyards" in the "Encyclopædia Britannica," and Editor of "Notes on Building Construction."*

Published by Longmans, Green & Co., 1907.

Contents: Manufacture, Physical and Chemical Qualities of Mild Steel.—Rolled Section in Steel.—Riveted Girder Work.—Practical Design of Columns and Struts.—Roof-Construction in Mild Steel and Iron.—Use of Mild Steel and Iron in Marine Engineering.—Protection of Steel Surfaces from Corrosion.

This work, like all those on construction with which Mr. Fidler's name is associated, is scientific, thorough and monumental, suitable for those students of considerable ability and remarkable industry who may hope for employment by H.M. Admiralty, or other clients who are not prevented from paying for high-class work by a desire to save the uttermost shilling. As an example of the spirit in which design and construction are treated may be noted the use of 7-lb. lead flashing for the finish of a corrugated iron roof. A valuable feature of the book is the record of actual experiment on struts and columns of wrought-iron, cast-iron, mild steel and hard steel. There are but a limited number of engineering students to whom the chapter on marine engineering is likely to be useful, but to these few it is most important and will convey information that is not easy to obtain. One might indeed say that this book is pre-eminently one for the embyro dockyard engineer, the remainder of the chapters, although of less limited interest, being as it were the stepping-stones to that on the use of mild steel and iron in marine engineering. The roofs, for example, of which instances are given, though not entirely so, are principally such as are required for dockyard purposes.

Standard Steel Construction, Compiled by Hall & Pickles, *Iron and Steel Merchants.*

Published by Sheratt & Hughes, London and Manchester, 1905.

Contents: Property Tables, Beam Tables and Strut Tables for Standard Sections of Angles, Tees, Zeds, Joists, Channels, Bulb Angles, and Bulb Tees.

This is an admirable book of sections of standard sizes of steelwork with the properties and capabilities of each, not only in single form but in built-up girders and stanchions. It is, therefore, a very handy compilation for affording assistance in the selection of suitable forms for varied items of construction. A most useful feature in the book is that of easily applied data as to the effect of eccentric loading on both beams and struts or stanchions, a matter that is too often overlooked by those whose knowledge is not very profound and who form a considerable proportion of those that are in the habit of using tables for the selection of sections. Most valuable are the two plates given showing in diagram fashion the economical values of varied types of stanchions and the shearing strength of girder webs.

A FRENCH BOOK.

Étude Expérimentale du Ciment Armé. [*Experimental Study of Reinforced Concrete.*] **By R. Feret.**

Paris : Gauthier-Villars, 1906

This important work, extending to nearly 800 pages, contains much that is original and much that should be of value to the engineer and to the designer of reinforced concrete structures. The author is the head of the Laboratoire des Ponts et Chaussées at Boulogne, and his book is based largely on his own experimental results and on methods of calculation introduced by him. The work is divided into four parts, of which the first is devoted to a description of tests made upon rectangular prisms and beams of concrete, reinforced in the simplest manner with round steel rods. In a large number of these tests the specimen under examination was repeatedly loaded and unloaded. The author considers it desirable to repeat these early experiments, which lead to conclusions of considerable practical importance, with the more refined means of measurement now available.

The second part deals with the theories and methods of calculation of stresses and strains in reinforced concrete. The mathematical treatment is elaborate, and the reader will be struck by the great use of graphical methods, which probably lend themselves better than any others to the practical purposes of the designer, when their theoretical basis has once been established with sufficient accuracy.

The third part consists of a bibliography of the subject, and those who are unacquainted with the extent to which reinforced concrete construction has already made its way on the Continent may be surprised to find that the mere enumeration of the titles of books and papers occupies no less than 138 pages. The references are classified under subject-headings.

The volume concludes with an account of numerous experiments on the resistance of concrete to compressive tensile and shearing stresses, and on the adhesion of concrete to steel. Here, again, free use is made of graphical methods, including the author's well-known diagram with triangular co-ordinates for indicating the dependence of the properties of mortar or concrete on its composition.

A GERMAN BOOK

Monolitat der Beton-Bauten. [*Monolithic Character of Concrete Structures.*] **N. A. Shitkewitsch.**

Ernst & Sohn, Berlin, 1906.

In this work, which is one of the most interesting of Messrs. Ernst's series, the author discusses the various conditions which affect the "monolithic character" of concrete structures; that is to say, the power of the concrete to act as a single material under changes of load, temperature, &c. With this object, the changes in volume due to the hardening process or to variation in the moisture, the expansion due to heat, and the elasticity under tensile and compressive stress, are brought into relation with the composition of the concrete mixture, and the conditions to which it is subjected during hardening. Geometrical considerations are introduced in dealing with the close packing of the aggregate, and the nature of the porosity produced by varying the proportions of the mixture from those necessary to bring about an exact filling of all voids is discussed.

All cements expand to a small extent on hardening in water, but in good cement the expansion is small. On hardening in air a contraction takes place, and this produces much more serious stresses in the concrete than the expansion in water, and increases with the richness of the mixture in cement. The best results are obtained with concretes made with a rich cement—sand mortar, used in quantity just insufficient to fill completely the voids of the aggregate. To avoid the appearance of horizontal cracks and fissures the concrete must be filled in uninterruptedly, and each layer must be roughened before adding the next. Examples illustrating the development of these cracks, and the conditions under which they occur, are given from fortification works.

Limits exist to the size of any concrete structure which can be rendered monolithic, dependent on the properties of the concrete, and on the influence of moisture, temperature, and conditions of setting. The greatest dimensions are reached when the construction is so arranged as to offer the least hindrance to changes of volume in the concrete. Larger structures must be treated as made up of separate parts, suitably tied together.

Concrete walls, &c., should be protected by stout, well-fitting shuttering during setting, and all upper surfaces covered by water-tight lids, so that the setting takes place as nearly as possible independently of the external atmospheric conditions.

The work deals in an interesting manner with several important points connected with concrete construction, which are not usually treated fully in the textbooks.

INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

THE SIEGWART FLOOR.

MR. HANS SIEGWART, of Lucerne (Switzerland), the inventor of the Siegwart Masts, described and illustrated on page 162 of this issue, has also patented in England and the Colonies a new flooring material known as the "Siegwart Beam." This system, which is already favourably regarded on the Continent, consists in manufacturing *mechanically*, hollow beams of reinforced concrete of a uniform breadth of 10 in., length up to 22 ft., and in five different heights (standard sizes)—viz., 3½, 4¾, 6. 7, and 8¼ in. The iron rods are placed in the sides of the beams, which are ridged to enable the cement to fill the spaces and form a solid mass of the whole floor.

The beams are delivered to the builder in a dry, hardened condition, and are simply laid together on the supporting walls or girders without scaffolding, and the joints filled with mortar. A floor thus laid can be used and loaded at once, as in addition to avoiding all shelling and the usual delay necessary for the drying of ordinary concrete, there are no troublesome supports and planking to be removed. The Siegwart System thus accelerates the progress of construction and the drying of the building.

Although very light in itself, the Siegwart floor possesses a great *guaranteed* supporting capacity, as, owing to the mechanical manufacture and protection during construction from the uncertainty of the weather, it is easy to secure a uniform result.

Some very interesting load and fire tests have been carried out at the Columbian University Fire Testing Station, New York, to determine the effect of a fire below a Siegwart floor for four hours at an average temperature of 1,700° Fahr., the floor carrying at the same time a distributed load of 150 lb. per sq. ft. After the fire water was applied on both sides under strong pressure, and when cool the same floor was loaded to 600 lb. per sq. ft. The deflections measured after this severe test were only slight, neither the Siegwart Beam or the girder protection appearing to have suffered any damage, and the Buildings Department of New York approved the Siegwart floor for general use in New York. Other loading tests made at Zurich, Berlin, Paris, Vienna, etc., gave equally good results, and the Siegwart Floor System is now making rapid headway, not only on the Continent, where twenty-five factories are now working the Siegwart patents, but also in Egypt, America, etc.

A Table of Strength for the standard sizes of the Siegwart Beams, together with any further information required, may be obtained at the offices of the International Siegwart Beam Co. at Lucerne, Switzerland.

Principal Articles Dealt with in Former Issues.

VOL. I.—NO. I.

The Advent of the Concrete Age	Lt.-Col. J. Winn, R.E., A.Inst.C.E.
Steel Skeleton Construction and The London Building Act	W. Noble Twelvetrees, M.I.Mech.E.
Reinforced Concrete at Munich (The New "Tietz" Stores)	
Reinforced Concrete for Foundations of Buildings	Charles F. Marsh, M.Inst.C.E., M.Am.Soc.C.E.
The Setting of Portland Cement, Article I. Part A	Cecil H. Desch, D.Sc., Ph.D.
The Preservation of Iron and Steel	B. H. Thwaite, C.E.

VOL. I.—NO. 2.

Reinforced Concrete in the United States	Capt. Sewell, U.S.A. Army.
Reinforced Concrete Piles in Tidal Waters	A. T. Walmisley, M.Inst.C.E.
The Setting of Portland Cement, Article I. Part B	Cecil H. Desch, D.Sc., Ph.D.
The Preservation of Iron and Steel. Part B	B. H. Thwaite, C.E.
Reinforced Concrete on the Great Western Railway	W. Armstrong, M.Inst.C.E.
Hollow Concrete Block Building Construction in the United States	S. B. Newberry, U.S.A.
Hair Cracks and other Minor Cracks in Concrete Surfaces	Albert Moyer.

VOL. I.—NO. 3.

The Historical Evolution of Reinforced Concrete in France	N. de Tedesco, Editor "Le Ciment," Paris.
Reinforced Concrete Bridges (I.)	W. Noble Twelvetrees, M.I.Mech.E.
The Setting of Portland Cement, Article II.	E. Candlot, Paris
Reinforced Concrete Water Mains	R. H. Wyrill, M.Inst.C.E.
The Theory of Reinforced Concrete	Capt. Sewell, U.S.A. Army.
Recent Examples of Steel and Concrete Buildings in Scotland	J. Roxburgh Sharman, A.M.Inst.C.E.
Hollow Concrete Blocks Used in the United States, and Their Patents	W. M. Torrance.

VOL. I.—NO. 4.

Reinforced Concrete as a Fire Resistant, Being Some Notes on the Constructional Lessons from San Francisco	Capt. Sewell, U.S.A. Army.
Some Reflections on Reinforced Concrete and Cement Uses after a Visit to the International Exhibition at Milan	Frederic R. Farrow, F.R.I.B.A.
The Setting of Portland Cement, Article III.	Cecil H. Desch, D.Sc., Ph.D.
Reinforced Concrete Bridges (II.)	W. Noble Twelvetrees, M.I.Mech.E.
Reinforced Concrete Railway Sleepers	G. H. Kimball, U.S.A.
Failures in Reinforced Concrete and Their Lessons (Collapse at Bâle)	
British Patent Rights and Reinforced Concrete Piles (Mouchel and Another *v.* Coignet and Others)	

VOL. I.—NO. 5.

The Historical Evolution of Reinforced Concrete in Germany	O. Kohlmorgen, Berlin.
The New French Rules as to Reinforced Concrete	(Translated specially.)
Reinforced Concrete Bridges (III.)	W. Noble Twelvetrees, M.I.Mech.E.
The Setting of Portland Cement, Article IV.	Professor M. Gary, Berlin.
Waterproofing Concrete on Fortification Work in the United States	Emile Low, M.Am.Soc.C.E.
The Working Drawings of a Reinforced Concrete Grain Silo at Lissa	
Fictitious "Portland" Cement	By A British Cement Maker.

VOL. I.—NO. 6.

The Historical Evolution of Reinforced Concrete in Italy	Oliviero Negri di Montenegro, Bologna.
Reinforced Concrete Bridges (IV.)	W. Noble Twelvetrees, M.I.Mech.E.
The Setting of Portland Cement, Article V.	Professor M. Gary, Berlin.
Steel and Concrete at the Ritz Hotel, London	
Failures in Reinforced Concrete, and Their Lessons, Article II. (Collapse of a Scenery Store at Berne)	
The New French Rules as to Reinforced Concrete (Some Additional Notes)	

VOL. II.—NO. 1.

The Progress of Reinforced Concrete in Great Britain during 1906	
The Application of Reinforced Concrete for the Construction of Fire-Resisting Buildings	James Sheppard, A.Inst.E.E.
The Setting of Portland Cement, Article VI.	D. B. Butler, A.M.Inst.C.E.
Failures in Reinforced Concrete, and Their Lessons (Collapse of Eastman Kodak Building, Rochester, N.Y.	
Some Early Examples of Reinforced Brickwork Tanks in Our Imperial Possessions	James Stewart, M.Inst.C.E.
A Few Experiments and Tests with Reinforced Concrete	R. T. Surtees, Newton-le-Willows.
The Theory and Application of Various Continental Methods of Calculations for Reinforced Concrete	N. de Tedesco, Editor "Le Ciment," Paris.
Licensees of Reinforced Concrete Systems (Mouchel *v.* Wm. Cubitt & Co.)	
Artificial Stones	

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume II. No. 3. JULY, 1907.

EDITORIAL NOTES.

CONCRETE AS A FACTOR IN BUILDING CONSTRUCTION.

The extraordinary increase in the attention accorded to concrete, reinforced concrete and its components, may be gathered from the fact that on no fewer than three occasions in a single week (namely, in that ending June 1st) did a number of influential members of the technical professions hold meetings in London to deal directly and indirectly with the subject.

In the first place there was the notable meeting at the Royal Institute of British Architects on the Monday night, at which Sir Henry Tanner, I.S.O., of H.M. Office of Works, presented the report of the Reinforced Concrete Committee, dealt with elsewhere. The President, Mr. Collcutt, architect of the Imperial Institute, was in the chair.

On the Tuesday there was an important meeting of the Engineering Standards Sub-Committee on Portland Cement, when the British cement standards were revised and brought up to date, and these are being made public as we go to press.

Again, on the Friday, the Specifications Sub-Committee of the Special Commission on Concrete Aggregates met, when the definitions for some of the principal aggregates suitable for concrete were considered.

It is a remarkable feature of our public life that at all these important meetings the work is done voluntarily and gratuitously by the members concerned, and civil engineers, architects, chemists, manufacturers and contractors vie with one another to give their best thought and attention to arriving at results that may not only be of practical use to the community of to-day, but should also give the British Empire buildings and engineering works in concrete that may in posterity do credit to the present age.

REINFORCED CONCRETE IN COUNTRIES SUBJECT TO EARTHQUAKES.

We have from time to time referred to the conflagration at San Francisco, which was caused by the earthquake shock of last year, and we have indicated how this conflagration proved in a most conclusive manner the advantages of good concrete and reinforced concrete in building construction when under the severe stress of conflagration temperatures.

We now observe that an important report on the disaster at San Francisco has been issued by the American Society of Civil Engineers, and this report bears out in every way what we have stated as to the stability of concrete and reinforced concrete from the fire point of view when properly applied with suitable aggregates, all steel being carefully protected.

But the report also points most emphatically to the advantages of concrete and reinforced concrete under earthquake shock, not only for buildings, but in civil engineering works. The report, for instance, plainly states that concrete dams are able to withstand earthquake shocks of the greatest severity without damage. The report states that concrete sewers on concrete pile foundations gave the most satisfaction, whilst practically all the masonry sewers were injured.

Coming from such an authoritive source, we anticipate future sewerage and water works in areas susceptible to earthquakes will be principally, if not entirely, of concrete and reinforced concrete, and it would be well to point out that this will probably also mean considerable saving, as this method of construction has the great advantage of comparatively low cost.

REINFORCED CONCRETE AND FIRE RESISTANCE.

We would call special attention to the proposed Rules for Reinforced Concrete of the American Board of Fire Underwriters, as far as they affect the question of fire prevention.

They are particularly interesting as indicating what experienced Insurance officials in the United States now require of reinforced-concrete buildings on which the advantages of the reduced tariff rates accorded to "fireproof" buildings will be obtainable. Summarised, the principal clause reads as follows, the italics being ours:—

> "Reinforced concrete . . . may be accepted for 'fireproof' buildings . . . provided that the aggregate for such concrete shall be hard-burned broken bricks, or terra-cotta, clean furnace clinker . . . clean broken stone, furnace slag, or clean gravel, together with clean, siliceous sand, if sand is required to produce a close and dense mixture; and provided, further, that the *minimum thickness of concrete surrounding and reinforcing members one-quarter inch or less in diameter shall be one inch; and for members heavier than one-quarter inch the minimum thickness of protection concrete shall be four diameters* . . . but no protecting concrete need be more than four inches thick for bars of any size; and provided, further, that *all columns and girders of reinforced concrete shall have at least one inch of material on all exposed surfaces over and above that required for structural purposes; and all beams and floor slabs shall have at least three-quarters inch of such surplus material for fire-resisting purposes;* but this shall not be construed as increasing the total thickness of protecting concrete as herein specified."

We refer elsewhere to the fire clauses of the Report of the Reinforced Concrete Committee of the R.I.B.A., which recommends 1½ in. to 2 in. protection as sufficient for structural parts. We, however, consider that the American requirements generally are more likely to meet the case of our growing fire hazards in commercial buildings.

CONCRETE AS A FIRE-RESISTING COVERING TO STEEL FRAMING.

In the preamble to these American Rules there is also a valuable reference to the protection of steelwork generally by concrete. It reads:—

> "The section of the Building Code submitted refers especially to structures of reinforced concrete throughout, but the rules are also generally applicable to concrete floors and roofs between steel beams and girders as far as they relate

> to preparation and handling of the concrete itself. *In such steel framed buildings concrete may safely be used for floor and roof slabs* and for insulation of steelwork, provided it is of the specified quality, is securely attached to the steel member by steel rods, expanded metal or woven wire, and is *thick enough to protect against penetration of heat, which thickness, in the opinion of the committee, should be not less than 4 in. on all columns, 2 in. around, and under all ordinary beams and girders, and 4 in. on the sides of large, heavily loaded girders in mercantile or storage buildings.*"

REINFORCED CONCRETE AND BRITISH FIRE OFFICES.

We recently published a valuable article on the subject of Fire Resistance and Reinforced Concrete, by Mr. James Sheppard, Surveyor to the North British and Mercantile Insurance Co. In the current issue will be found another most useful contribution, *i.e.*, a paper presented by Mr. F. A. Macdonald to the Insurance Institute of Edinburgh.

This paper, coming from a representative of one of the leading specialist firms trading in Great Britain, and being a technical argument as distinct from the salesman's laudation, claims the attention of both Fire Office Committee and The British Fire Prevention Committee. We are not in accord with the author on some matters of detail, such as concrete aggregates, but generally on matters of principle our views coincide.

THE INTERNATIONAL COMMISSION ON REINFORCED CONCRETE.

Our notice has been called to the issue of a programme of work for the International Commission on Reinforced Concrete, and we observe that the following are the first four points to which attention will be accorded:

A.—A summary of tests completed in different countries.

B.—A summary of the facts definitely established by these tests.

C.—A summary of the chief causes of difference of opinion on questions relating to reinforced concrete.

D.—A set of standards for future tests.

Upon C will then arise an oral discussion as to the best means of settling the items of difference, and the drafting of a further programme of any investigations necessary, with the view of settling such differences.

FAILURES IN REINFORCED CONCRETE.

Our policy of calling attention to occasional failures in reinforced concrete work having been questioned by interested parties, we think it would be a benefit to those concerned generally in the industry of reinforced concrete to note the words of Mr. Edward T. Cairns, chairman of the Committee on Cement for Building Construction, in a paper which he presented at a conference at New York in May. He said:—

> "While calling attention to the unusual number of such failures occurring in the last year it is only fair to admit that the number of buildings erected is also very much greater than in any previous year, and the proportion of failures may not be so much larger. Moreover, it is very encouraging to notice the extensive discussion which these failures have provoked in engineering journals, and the widespread condemnation by the public in general, of the methods which have allowed these accidents, all of which must naturally tend to prevent, in some measure, the repetition of the errors in future, by making it a commercial necessity for concrete builders to regulate this personal element, which is especially

prominent in concrete work, in order to insure a sufficient degree of public confidence to secure permanence of their industry."

We need hardly say that we fully concur with Mr. Cairns's views. We both recognise that happily the proportion of failures to the number of reinforced-concrete buildings is rapidly decreasing, and we welcome the exhaustive discussion of accidents in the technical Press as a likely remedy to their recurrence.

The prevention of serious failures in reinforced concrete in this country is a matter of vital importance to the industry concerned, more particularly because in this country a certain amount of prejudice still exists against this form of construction, and any one serious accident, much more so a series, would lead to legislative measures being put in force which would inevitably retard the proper development of this excellent form of construction in our large urban centres.

One of the results of the recent discussion on failures is, we are glad to note, the issue of various most excellent rules and guides by specialist firms for the benefit of their customers and contractors generally. If intelligently followed, these guides should practically preclude accidents.

THE INTERNATIONAL TESTING ASSOCIATION AND CEMENT.

The work of the International Testing Association for its conference at Copenhagen in 1909 has already been defined at the meeting of the Executive held at Munich, and we observe that much attention will be accorded to questions relating to Portland cement.

We print below the list of questions that will be considered, each question being known as a "problem." The "problems" are as follows:—

Problem No. 12.—Investigation on the behaviour of cements as to time of setting, and on the best method for determining the beginning and the duration of the process of setting.

Problem No. 30.—Determination of the simplest method for the separation of the finest particles in Portland cement by liquid and air process. Chairman, Prof. Max Gary, Berlin.

Problem No. 31.—On the behaviour of cements in sea water.

Problem No. 32.—On accelerated tests for the constancy of volume of cements. Chairman, Mr. Bertram Blount, F.C.S., London.

Problem No. 33.—On the influence of the proportion of water and sand on the strength of Roman and other cements.

Problem No. 42.—Uniform tests of hydraulic cements by prisms and determination of a standard sand. Chairman, Prof. F. Schüle, Zürich.

Regarding the problem No. 30 referred to above, on the fineness of Portland Cement, which is a matter of the utmost importance in this country, we would observe that the sub-committee in charge comprises Professor Gary (Berlin), as chairman, with Mr. H. K. G. Bamber (London), Dr. R. Dyckerhoff (Biberich), Mons. Lejeune (de Teil), Mons. Maintz-Petersen (Copenhagen), and Mons. Mesnager (Paris), and that this committee will have the co-operation of the officials and staff of the Testing Laboratory of the Zürich Technical College.

REPORT of THE COMMITTEE ON REINFORCED CONCRETE

Formed under the auspices of

THE ROYAL INSTITUTE OF BRITISH ARCHITECTS

The long-looked-for Report of the Reinforced Concrete Committee, formed under the auspices of the Royal Institute of British Architects, is presented herewith, together with some Editorial comments. With the Report were published four appendices on matters relating to the Methods of Calculations.—ED.

THE Report of the Reinforced Concrete Committee, formed under the auspices of the Royal Institute of British Architects, has now been issued. It should be of material assistance to those members of the technical professions who have been wavering as to the application of this form of building construction, pending the publication of independent data compiled by British colleagues.

Data, reliable, independent, and all-sufficient, have long been issued by Governments and Professional Societies of almost every country on the Continent of Europe, whilst in the United States there has been a veritable galaxy of Rules and Regulations issued by public bodies of various descriptions.

But although pioneers in the application of reinforced concrete fully thirty years back, this method of construction has been sorely neglected in our islands, and even its technical peculiarities have been overlooked by British scientists, until quite lately the Continental and American works executed in reinforced concrete attracted attention in London, and some of the more active of the foreign specialist firms sent their representatives to our Metropolis.

Perhaps at this point it would not be out of place to indicate that, as far as the present advancement of building construction by the application of reinforced concrete is concerned, the technical professions at home have to thank two men in particular for the propagation of its application in this country.

We refer in the first place to Mr. Charles F. Marsh, M.Inst.C.E., who has, by his able writings, practically taught his British colleagues what reinforced concrete is, and how it may best be applied.

In the next place we would also refer to Mr. L. G. Mouchel (General Agent for the Hennebique system), who, by his great technical ability and high skill in commercial organisation, was able, despite all the disadvantages he was labouring under, to put reinforced concrete upon the British market on a large scale, and to enlist the assistance of a number of contractors.

We are occasionally at variance with some of the technical details in

Mr. Marsh's findings. We similarly do not always agree with Mr. Mouchel's methods of propagation. But to both, in their respective spheres, must be primarily attributed the commencement of the Reinforced Concrete Age as far as Great Britain is concerned.

It is, in fact, also generally considered to be mainly due on the one hand to the influence of Mr. Marsh—who was desirous of obtaining some independent ruling in this country as to reinforced concrete—and on the other to the desire of certain well-known architects to thwart what they thought—rightly or wrongly—to be an effort on Mr. Mouchel's part to make a monopoly of his system of design, that the Reinforced Concrete Committee was brought into being by the Royal Institute of British Architects.

As to the Committee and its Report, we would wish to say much both favourable as also by way of criticism, but we think it may be more in the interests of the subject we have at heart to limit our comments for the moment, and publish the Report as it stands.

The Report must, in any case, be looked upon as a provisional one only, for it is very insufficient in certain respects, and can scarcely carry that weight of authority among engineers that is essential for the development of reinforced concrete in great public works. The Report should preferably be simply looked upon as an intermediate step in the right direction, pending action and the standardisation of the subject by the Engineering Standards Committee. But for all that the Report, as far as it goes, is, as we have already said, a very useful one.

In the first place it may be looked upon as a recognition of reinforced concrete as a factor in building construction. It also serves as a compromise between various extremist views. It should further serve as a warning against carelessness, and it gives such members of the technical professions who do not care to think for themselves a handy guide and some useful general data for calculating or checking figures. The Report, it is true, contains blunders, some clerical as well as some of fact. It is stated, for instance, that fires have proved that 1½ in. to 2 in. of concrete affords sufficient protection to the structural parts. Fires have proved exactly the reverse. Yet, for all that, the general principles as to fire protection laid down are sound, and if followed should result in a vast improvement in reinforced concrete buildings compared with what has occurred owing to the fire aspect, common with us during earlier days, and still common on the Continent. Here, by the bye, we would put in a query, namely, what is *cinder* as referred to in the Report? We know of coke breeze and of clinker, but we have doubts as to there being a trade term "cinder" in this country. An erroneous and very confusing Americanism has apparently been used.

The "Methods of Calculation" appended to the Report throw the field of reinforced concrete designing open to all comers, with a slight advantage to the disciples of the Hennebique practice. As to the data in respect to steel, however, we think that the question of ultimate strength of steel, its elasticity, etc., has been treated on too conservative lines.

But, as indicated, we must limit our comments, and would close by expressing our appreciation of the trouble taken by the members of the Committee in the preparation of the Report, which, if not exactly perfect, certainly speaks for much painstaking effort, especially on the part of the majority of the members, who unfortunately did not have that great helpmate at their disposal, namely, *practical experience* of reinforced concrete work.

We would specially congratulate Sir Henry Tanner, I.S.O. (Principal Architect to H.M. Office of Works), the Chairman of the Committee, on the able way in which, with great tact and skill, he has guided the Committee to a result of their labours which obviously necessitated some difficult compromises. The Honorary Secretary's laborious task of collating data should likewise not be overlooked.

Sir Henry Tanner's views on Reinforced Concrete.

One last remark as to Sir Henry Tanner's assistance to the Committee and enhancement of its authority; that is to say that some of his words when answering the vote of thanks at the Royal Institute of British Architects will, we believe, be found in after years to have been of the greatest possible service in promoting the advancement of reinforced concrete in the Empire. We quote these observations, for they claim, to our mind, close attention. Sir Henry Tanner, in responding to a vote of thanks at the Royal Institute of British Architects on May 27th, said:—

> "That those who had made a study of reinforced concrete had, of course, great regard for it in the future. So far as he himself was concerned, he had started about three works with it, one of which was rather a large one, so that he had some sort of faith in the work. As to economy, there was no question about it. One of the works he had in hand in this material cost about twopence a cubic foot for the carcase—of course, without any finishings, merely the reinforced concrete. They could not touch that under certainly twice the sum of money in any other material. . . . .
>
> "There was, of course, not much art about reinforced concrete. It was really a practical matter, and one could not get much beauty out of it, he must confess; but, at the same time, in works of any magnitude it was incumbent upon architects to make use of it where cost was of any moment. Wherever one could economise there was no object in spending money; therefore it was a right thing to use. Other materials could be used for the fronts and all the visible parts where appearance had to be considered. It was no good burking the question; reinforced concrete would have to be used. . . . .
>
> "Then if the architect chose to go to a specialist to devise such a building for him, he did not see how he could get away from the responsibility entirely. He himself had employed an agent of a well-known patent in two cases; but he (the speaker) had to bear the brunt if anything went wrong; therefore he had to see that what the specialist was doing was likely to prove satisfactory. He did not think his department would be satisfied with him altogether if anything happened to one of those buildings which he had suggested should be put up, notwithstanding that they employed a specialist, and paid him his percentage, just as they should any engineer they employed. . . . .
>
> "His experience was not very old in this material, but at the same time he had great faith in it, and that, he thought, he had shown."

THE TEXT OF THE REPORT.

1. Reinforced concrete is used so much in building and engineering construction that a general agreement on the essential requirements of good work is desirable.

The proposals which follow are intended to embody these essentials, and to apply generally to all systems of reinforcement.

Good workmanship and materials are essential in reinforced concrete. With these and good design structures of this kind appear to be trustworthy. It is essential that the workmen employed should be skilled in this class of construction.

Very careful superintendence is required during the execution of the work in regard to—

(*a*) The quality, testing, and mixing of the materials.

(*b*) The sizes and positions of the reinforcements.

(*c*) The construction and removal of centering.

(*d*) The laying of the material in place and the thorough punning of the concrete to ensure solidity and freedom from voids.

If the metal skeleton is properly coated with cement, and the concrete is solid and free from voids, there is no reason to fear decay of the reinforcement in concrete of stone, gravel, cinder, coke-breeze, etc., made with clean fresh water.

2. The by-laws regulating building in this country require external walls to be in brick, or stone, or concrete of certain specified thicknesses. In some places it is in the power of the local authorities to permit a reduced thickness of concrete when it is strengthened by metal; in other districts no such power has been retained. We are of opinion that all by-laws should be so altered as to expressly include reinforced concrete amongst the recognised forms of construction.

A section should be added to the by-laws declaring that when it is desired to erect buildings in reinforced concrete complete drawings showing all details of construction and the sizes and positions of reinforcing bars, a specification of the materials to be used and proportions of the concrete, and the necessary calculations of strength based on the rules contained in this report, signed by the person or persons responsible for the design and execution of the work, shall be lodged with the local authority.

3. FIRE RESISTANCE.—(*a*) Floors, walls, and other constructions in steel and concrete formed of incombustible materials prevent the spread of fire in varying degrees according to the composition of the concrete, the thickness of the parts, and the amount of cover given to the metal.

(*b*) Experiment and actual experience of fires show that concrete in which limestone is used for the aggregate is disintegrated, crumbles and loses coherence when subjected to very fierce fires, and that concretes of gravel or sandstones also suffer, but in a rather less degree.* The metal reinforcement in such cases generally retains the mass in position, but the strength of the part is so much diminished that it must be renewed.

Concrete in which coke-breeze, cinders or slag form the aggregate is only superficially injured, does not lose its strength, and in general may be repaired. Concrete of broken brick suffers more than cinder concrete and less than gravel or stone concrete.

(*c*) The material to be used in any given case should be governed by the amount of fire resistance required as well as by the cheapness of, or the facility of procuring, the aggregate.

(*d*) Rigidly attached web members, loose stirrups, bent-up rods, or similar means of connecting the metal in the lower or tension sides of beams or floor slabs (which sides suffer most injury in case of fire) with the upper or compression sides of beams or slabs not usually injured, are very desirable.

(*e*) For main beams covering of 1½ in. to 2 in. of concrete over the metal reinforcement appears from experience in actual fires to afford ample protection to the structural parts. In floor slabs the cover required may be reduced to 1 in.

---

* The smaller the aggregate the less the injury.

All angles should be rounded or splayed to prevent spalling off under heat.

(*f*) More perfect protection to the structure is required under very high temperature, and in the most severe conditions it is desirable to cover the concrete structure with fire-resisting plastering which may be easily renewed.

Columns may be covered with coke-breeze concrete, terra-cotta, or other fire-resisting facing.

MATERIALS.

4. *Cement.*—Only Portland cement complying with the requirements of the specifications adopted by the British Engineering Standards Committee should be employed; in general the slow-setting quality should be used. Every lot of cement delivered should be tested, and in addition the tests for soundness and time of setting, which can be made without expensive apparatus, should be applied frequently during construction.

The cement should be delivered on the work in bags or barrels bearing the maker's name, and the weight of the cement contained.

5. *Sand.*—The sand should be composed of hard grains of various sizes up to particles which will pass a quarter-inch square mesh, but of which at least 75 per cent. should pass ⅛-in. square mesh. Fine sand alone is not so suitable, but the finer the sand the greater is the quantity of cement required for equal strength of mortar. It should be clean and free from ligneous, organic, or earthy matter. The value of a sand cannot always be judged from its appearance, and tests of the mortar prepared with the cement and the sand proposed should always be made. Washing sand does not always improve it, as the finer particles which may be of value to the compactness and solidity of the mortar are carried away in the process.

6. *Aggregate.*—The aggregate, consisting of gravel, hard stone, or other suitable material, should be clean and angular, varied in size as much as possible between the limits of size allowed for the work. In all cases material which passes a sieve of a quarter-inch mesh should be reckoned as sand. The maximum allowable size is usually ¾ in. The maximum limit must always be such that the aggregate can pass between the reinforcing bars and between these and the centering.

The sand should be separated from the gravel or broken stone by screening before the materials are measured.

7. *Proportions of the Concrete.*—In all cases the proportions of the cement, sand, and aggregate should be separately specified in volumes.

As the strength and durability of reinforced concrete structures depend mostly on the concrete being properly proportioned, it is desirable that in all important cases tests should be made as described herein with the actual materials that will be used in the work before the detailed designs for the work are prepared.

In no case should less dry cement be added to the sand when dry than will suffice to fill its interstices, but subject to that the proportions of the sand and cement should be settled with reference to the strength required, and the volume of mortar produced by the admixture of sand and cement in the proportions arranged should be ascertained.*

The interstices in the aggregate should be measured and at least sufficient mortar

---

* For convenience on small works the following figures may be taken as a guide, and are probably approximately correct for medium silicious sand :—

Parts Cement.		Parts Sand.		Parts Mortar.	Parts Cement.		Parts Sand.		Parts Mortar.
1	+	½	=	1·20	1	+	2	=	2·35
1	+	1	=	1·50	1	+	2½	=	2·70
1	+	1½	=	1·90	1	+	3	=	3·00

allowed to each volume of aggregate to fill the interstices and leave at least 10 per cent. surplus.

For ordinary work a proportion of one part of cement to two parts sand will be found to give a strong, practically watertight mortar, but where special watertightness or strength is required the proportion of cement must be increased.

The amount of cement added to the aggregate should be determined on the work by weight. The weight of a cubic foot of cement for the purpose of proportioning the amount of cement to be added may be taken at 90 lb.

8. *The metal* used should be steel having the following qualities:—

(*a*) An ultimate strength of not less than 60,000 lb. per sq in.

(*b*) An elastic limit of not less than 50 per cent., or more than 60 per cent. of the ultimate.

(*c*) An elongation of not less than 22 per cent. in the lengths stated below.

(*d*) It must stand bending cold 180 deg. to a diameter of the thickness of pieces tested without fracture on outside of bent portion.

In the case of round bars the elongation should not be less than 22 per cent., measured on a gauge-length of eight diameters. In the case of bars over one inch in diameter the elongation may be measured on a gauge-length of four diameters, and should then be not less than 27 per cent. For other sectional material the tensile and elongation tests should be those prescribed in the British Standard Specification for Structural Steel.

Before use in the work the metal must be clean and free from scale or loose rust. It should not be oiled or painted, but a wash of thick Portland cement grout is desirable.

Welding should in general be forbidden; if it is found necessary, it should be at points where the metal is least stressed, and it should never be allowed without the special sanction of the architect or engineer responsible for the design.

The reinforcement ought to be placed and kept exactly in the positions marked on the drawings, and, apart from any consideration of fire resistance, ought not to be nearer the surface of the concrete at any point than 1 in. beams and ½ in. in floor slabs or other thin structures.

9. *Mixing: General.*—In all cases the concrete should be mixed in small batches and in accurate proportions, and should be laid as rapidly as possible.

Hand-mixing.—When the materials are mixed by hand they are to be turned over and thoroughly mixed on a clean platform until the colour of the cement is uniformly distributed over the aggregate.

Machine-mixing.—Whenever practicable the concrete should be mixed by machinery.

10. *Laying.*—The thickness of loose concrete that is to be punned should not exceed three inches before punning, especially in the vicinity of the reinforcing metal. Special care is to be taken to ensure perfect contact between the concrete and one reinforcement, and the punning to be continued till the concrete is thoroughly consolidated. Each section of concreting should be as far as possible completed in the operation; when this is impracticable, and work has to be recommenced on a recently laid surface, it is necessary to wet the surface; and where it has hardened it must be hacked off, swept clean, and covered with cement grout. Work should not be carried on when the temperature is below 34 deg. Fahr. The concrete when laid should be protected from the action of frost, and shielded against too rapid drying from exposure to the sun's rays or winds, and kept well wetted. All shaking and jarring must be

avoided. The efficiency of the structure depends chiefly on the care with which the laying is done.

Water.—The amount of water to be added depends on the temperature at the time of mixing, the materials, and the state of these, and other factors, and no recommendation has therefore been made. Sea-water should not be used.

1. *Centering or Casing.*—The centering must be of such dimensions, and so constructed, as to remain rigid and unyielding during the laying and punning of the concrete. It must be so arranged as to permit of easing and removal without jarring the concrete. Provision should be made wherever practicable for splaying or rounding the angles of the concrete. Timber when used for centering may be advantageously limewashed before the concrete is deposited.

12. *Striking of Centres.*—The time during which the centres should remain up depends on various circumstances, such as the dimensions or thickness of the parts of the work, the amount of water used in mixing, the state of the weather during laying and setting, etc., and must be left to the judgment of the person responsible for the work. The casing for columns, for the sides of beams, and for the soffits of floor slabs not more than 4 ft. span must not be removed under eight days; soffits of beams and of floors of greater span should remain up for at least fourteen days, and for large span arches for at least twenty-eight days. The centering of floors in buildings which are not loaded for some time after the removal of same may be removed in a short time. The centering for structures which are to be used as soon as completed must remain in place much longer. If frost occurs during setting, the time should be increased by the duration of the frost.

13. *Testing.*—Before the detailed designs for an important work are prepared, and during the execution of such a work, test pieces of concrete should be made from the cement, sand, and aggregate to be used in the work, mixed in the proportions specified. These pieces should be either cubes of not less than four inches each way, or cylinders not less than four inches diameter, and of a length not less than the diameter. They should be prepared in moulds, and punned as described for the work. Not less than four cubes or cylinders should be used for each test, which should be made twenty-eight days after moulding. The pieces should be tested by compression, the load being slowly and uniformly applied. The average of the results should be taken as the strength of the concrete for the purposes of calculation, and in the case of concrete made in proportions of 1 cement, 2 sand, 4 hard stone the strength should not be less than 2,400 lb. per sq. in.

Loading tests on the structure itself should not be made until at least two months have elapsed since the laying of the concrete. The test load should not exceed one and a half times the accidental load. Consideration must also be given to the action of the adjoining parts of the structure in cases of partial loading. In no case should any test load be allowed which would cause the stress in any part of the reinforcement to exceed two-thirds of that at which the steel reaches its elastic limit.

METHODS OF CALCULATION.

DATA.

1. *Loads.*—In designing any structure there must be taken into account: (*a*) The weight of the structure. (*b*) Any other permanent load, such as flooring, plaster, etc. (*c*) The accidental load.* (*d*) In some cases also an allowance for vibration and shock.

Of all probable distributions of the load, that is to be assumed in calculation which will cause the greatest straining action.

(1) The weight of the concrete and steel structure may be taken at 150 lb. per cubic foot.

(2) In structures subjected to very varying loads and more or less vibration and shock as, for instance, the floors of public halls, factories, or workshops, the allowance for shock may be taken equal to half the acciden-

---

* By accidental load is meant the imposed load additional to the weight of the structure for which the structure is calculated.

tal load. In structures subjected to considerable vibration and shock, such as floors carrying machinery, the roofs of vaults under passage ways and courtyards, the allowance for shock may be taken equal to the accidental load.

(3) In the case of columns or piers in buildings, which support three or more floors, the load at different levels may be estimated in this way. For the part of the roof or top floor supported, the full accidental load assumed for the floor and roof is to be taken. For the next floor below the top floor 10 per cent. less than the accidental load assumed for that floor. For the next floor 20 per cent. less, and so on to the floor at which the reduction amounts to 50 per cent. of the assumed load on the floor. For all lower floors the accidental load on the columns may be taken at 50 per cent. of the loads assumed in calculating those floors.

BEAMS.

2. *Spans.*—These may be taken as follows:—For beams the distance from centre to centre of bearings. For slabs supported at the ends, the clear span + the thickness of slab. For slabs continuous over more than one span the distance from centre to centre of beams.

3. *Bending moments.*—In the most ordinary case of a uniformly distributed load of w lb. per inch run of span the bending moments will be as follows:—

(*a*) *Beam or slab simply supported at the ends.* Greatest bending moment at centre of span of l inches is equal to $wl^2/8$ inch lb.

(*b*) *Beam continuous over several spans, or encastré or fixed in direction at each end.* The greatest bending moments are at the ends of the span, and the beam should be reinforced at its upper side near the ends. If continuity can be perfectly relied on, the bending moment at the centre of the span is $wl^2/24$, and that over the supports $-wl^2/12$. If the continuity is in any way imperfect, the bending moment at the centre will in general be greater, and that at the supports less, but the case is a very indefinite one. It appears desirable that generally in building construction the centre bending moment should not be taken less than $wl^2/12$. The bending moment at the ends depends greatly on the fixedness of the ends in level and direction. When continuity and fixing of the ends, whether perfect or imperfect, is allowed for in determining the bending moment near the middle of the span, the beam or slab must be designed and reinforced to resist the corresponding bending moments at the ends.

When the load is not uniformly distributed the bending moments must be calculated on the ordinary statical principles.

4. *Stresses.*—The internal stresses are determined as in the case of a homogeneous beam, on these approximate assumptions:—

(*a*) The coefficient of elasticity in compression of stone or gravel concrete, not weaker than 1 : 2 : 4, is treated as constant and taken at one-fifteenth of the coefficient of elasticity of steel.

		lbs. per sq. in.
Coefficient for concrete	$= E_c =$	2,000,000
„ „ steel	$= E_s =$	30,000,000

$$\frac{E_s}{E_c} = 15.$$

It follows that at any given distance from the neutral axis, the stress per sq. in. on steel will be fifteen times as great as on concrete.

(*b*) The resistance of concrete to tension is neglected, and the steel reinforcement is assumed to carry all the tension.

(*c*) The stress on the steel reinforcement is taken as uniform on a cross section, and that on the concrete as uniformly varying.

5. *Working Stresses.*—If the concrete is of such a quality that its crushing strength is 2,400 to 3,000 lb. per sq. in. after twenty-eight days, and the steel has a tenacity of not less than 60,000 lb. per sq. in., the following stresses may be allowed:—

	lbs. per sq in.
Concrete, in compression in beams subjected to bending	600
Concrete in columns under simple compression	500
Concrete in shear in beams ...	60
Adhesion * of concrete to metal ...	100
Steel in tension	15,000 to 17,000

When the proportions of the concrete differ from those stated above the stress in compression allowed in beams may be taken at one-fourth, and that in columns at one-fifth of the crushing stress of cubes of the concrete of sufficient size at twenty-eight days after gauging. If stronger steel is used than that stated above, the allowable tensile stress may be taken at one-half the stress at the yield point of the steel.

Approximate Calculations.

Let b be the width and d the effective depth of the beam in inches.

$A = bd$ the area of cross-section.

$m = E_s/E_c$ the ratio of the coefficients of elasticity of steel and concrete.

M = bending moment at the section considered, in inch-pound units.

t = tensile stress in metal in lbs. per square inch.

c = compressive stress in concrete per square inch.

z = distance of resultant thrust in concrete from compressed edge of beam in inches.

kd = distance of neutral axis from compressed edge in inches.

$A_c = kbd$ = area of concrete in compression in square inches.

A_t = area of metal in tension in square inches.

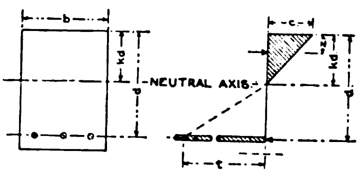
$p = A_t/bd$ the ratio of section of metal to section of concrete.

l = span in inches.

w = load per inch run of span.

---

* It is desirable that the reinforcing rods should be so designed that the adhesion is sufficient to resist the shear between the metal and concrete. Precautions should in every case be taken by splitting or bending the rod ends or otherwise to provide additional security against the sliding of the rods in the concrete.



A568

(a) Beams of rectangular section with single reinforcement.

In a homogeneous beam the stresses are proportional to the distances from the neutral axis. In a discrete beam, such as a beam of concrete and steel, on account of the greater rigidity of steel, at a given distance from the neutral axis the stress in the steel will be *m* times as great as in concrete. Hence—

$$\frac{mc}{t}=\frac{kd}{d(1-k)}=\frac{k}{1-k}.$$

But equating the total tension and compression

$$\tfrac{1}{2}\,cbkd=pbdt$$
$$ck=2\,pt.$$

Replacing *c* in terms of *t*

$$\frac{k^2}{m(1-k)}=2\,p$$
$$k=\sqrt{(p^2m^2+2pm)}-pm.$$

Thus for

$m=$	$p=$	$k=$
15	·007	·365
15	·010	·417
15	·015	·483
15	·020	·530

That is, the neutral axis is lower as the amount of reinforcement is greater, and passes the half depth for 2 per cent. of reinforcement.

The distance of the resultant thrust from the compressed edge is

$$z=\tfrac{1}{3}kd$$

Equating the moments of resistance to the bending moment,

$$M=A_t t(d-\tfrac{1}{3}kd)=\tfrac{1}{2}A_c c(d-\tfrac{1}{3}kd)$$

$$t=\frac{}{A_t d(1-\frac{1}{3}k)}=\frac{M}{pbd^2(1-\frac{1}{3}k)}$$

$$c=\frac{2M}{A_c d(1-\frac{1}{3}k)}=\frac{2M}{kbd^2(1-\frac{1}{3}k)}.$$

The shearing stresses and tensions near the ends of the beam are usually resisted by stirrups or inclined steel bars, and it is always desirable to bend upwards near the supports one or more of the reinforcing bars when the reduced bending moments at the ends permit of so doing. Stirrups or rigidly attached web members or inclined bars should be provided in all cases where the average shearing stress on a vertical section of the beam exceeds 60 lb. per sq. in. of the section. A theoretical determination of the section required for these would be very difficult. If the simple case is taken of a uniformly loaded beam, supported at the ends with horizontal steel tension bars not bent up at the ends, the adhesion between concrete and steel which is required may be found thus: The difference of tension in 1-foot length of bars at the end of the span will be the tangential force between steel and concrete in that distance. The bending moment at the end is 0, and at 1 foot from the end $6w\,(l-12)$ inch-pounds, where *w* is the load per inch run. Hence the increment of tension between the end and 1 foot from the end is

$$\frac{6w(l-12)}{d(1-\frac{1}{3}k)}\text{ lb.}$$

If ψ is the total perimeter of the reinforcing bars, the adhesion stress is

$$\frac{w(l-12)}{2\psi d(1-\frac{1}{3}k)}\text{ lb. per sq. in.}$$

(b) Beams of **T** *Section with Single Reinforcement.*

In designing **T** beams where the upper flange forms a floor, the thickness d_1 of this will first be ascertained by considering the part between two ribs as a slab, having its own reinforcing bars transverse to the rib. The whole of this cannot in general be considered to form part of the upper flanges of the **T** beams. The width b_1 of the upper flange may be assumed to be not greater than one-third the span of the beams, or than three-fourths of the distance from centre to centre of the reinforced ribs.* The depth *d* should then be determined with reference to the stiffness required in the floor. In general *d* is from $\frac{1}{12}$th to $\frac{1}{15}$th of the span.

Two cases arise according as the thickness of flange is greater or less than *kd*, the distance from the neutral axis to the compressed edge. In the former case ($d\quad kd$) the rules under (*a*) apply if *b* is substituted for *b*, and $A=b_1d_1+b(d-d_1)$ for *bd*. The equations then become

$$\frac{mc}{t}=\frac{k}{1-k}$$

$$k=\sqrt{\left(\frac{2pAm}{b_1d}+\frac{p^2A^2m^2}{b_1{}^2d^2}\right)}-\frac{pAm}{b_1d}$$

$$=\sqrt{\left(\frac{2A_tm}{b_1d}+\frac{A_t{}^2m^2}{b_1{}^2d_1{}^2}\right)}-\frac{A_tm}{b_1d}$$

$$z=\tfrac{1}{3}kd$$

$$t=\frac{M}{A_td(1-\frac{1}{3}k)}=\frac{M}{pAd(1-\frac{1}{3}k)}$$

$$c=\frac{2M}{A_cd(1-\frac{1}{3}k)}=\frac{2M}{kb_1d^2(1-\frac{1}{3}k)}$$

---

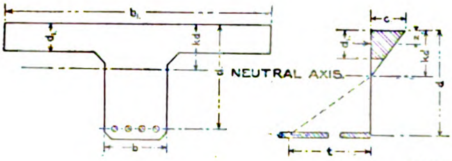
* There is no satisfactory theoretical determination of the precise amount of the floor slab acting with the web.

where $pA = A_t$ the section of reinforcement. The increment of tension in one foot length at the end of the beam and the adhesion stress is the same as in (*a*).

When d_1 is less than kd the small compression in the web between d_1 and kd may be neglected.

Let, as before, the whole area of section $= A = b\,d_1 + b(d - d_1)$, and pA be the area of reinforcement.

$$\frac{mc}{t} = \frac{k}{1-k}$$



A 569

The mean compressive stress on the flange is

$$\tfrac{1}{2}\left\{c + c\frac{kd - d_1}{kd}\right\} = \frac{c}{2}\,\frac{2kd - d_1}{kd}.$$

Equating the total tension and compression,

$$A_t t = pAt = \tfrac{1}{2} b_1 d_1 c \frac{2kd - d_1}{kd}$$

$$kd = \frac{b_1 d_1^2 + 2pAmd}{2b_1 d_1 + 2pAm} = \frac{b_1 d_1^2 + 2A_t md}{2b_1 d_1 + 2A_t m}.$$

But $z = \dfrac{d_1}{3}.\dfrac{3kd - 2d_1}{2kd - d_1}$.

Equating the moments

$$M = A_t t(d - z) = pAt(d - z)$$

$$= \tfrac{1}{2} b_1 d_1 c \frac{2kd - d_1}{kd}(d - z)$$

$$t = \frac{M}{pA(d - z)}$$

$$c = \frac{2Mkd}{b_1 d_1 (2kd - d_1)(d - z)}.$$

It may be useful also to point out that the area of reinforcement for a given value of c/t is

$$A_t = pA = \frac{c}{t} \cdot \frac{b_1 d_1 (2kd - d_1)}{2kd}.$$

(*c*) *Slabs supported or fixed on more than two sides.*

It does not appear that there is either a satisfactory theory or trustworthy experiments from which the strength of rectangular slabs supported or fixed on all four edges can be determined.

COLUMNS OR PIECES SUBJECTED TO THRUST.

The reinforcement of columns should in general amount to at least 0·8 per cent. of the gross cross-section. The liability to bending of the longitudinal reinforcing bars greatly weakens the column, and should be prevented by steel binding bars. Some theoretical considerations would indicate that cross binding is required at points not further apart than twenty-four times the least lateral dimension of the reinforcing rods. But experiment shows that still closer cross binding, or better, spiral binding,[*] greatly increases the strength of the column.

(*a*) *Short Columns Axially Loaded.*

If the load is strictly axial the stress is uniform on cross-sections. Let A_c be the cross-section of the column (including the reinforcement), and A the equivalent section as defined below, *a* the section of longitudinal reinforcing bars, P the load on the columns in lbs. Let *c* be the stress on the concrete, and *t* that on the steel, the ratio of the coefficients of elasticity being *m*.

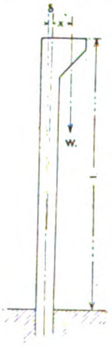
$$c = \frac{P}{A_c + (m-1)a} = \frac{P}{A}$$

$$t = \frac{mP}{A_c + (m-1)a} = \frac{mP}{A}$$

It appears that *c* may be taken = 500 lb. per sq. in., $t = 7{,}500$ lb. per sq. in., and $E_s/E_c = m = 15$.

When the stress on the concrete is not greater than 500 lb. per sq. in., lateral bending of the column as a whole is not to be feared if the ratio of length to the least lateral dimension is not greater than 18.

(*b*) *Columns Eccentrically Loaded.*



If a column initially straight is loaded eccentrically, as when a beam rests on a bracket attached to the column, it may be regarded as fixed at the base and free at the loaded end. Then it must bend in the plane passing through the load, the deflection at the top being δ. Let x be the eccentricity of the load measured from the centre of the column when straight. Then the bending moment at the base of the column is $W(\delta + x)$. But it is known that δ will be small compared with x, provided that W is small compared with $2EI/l^2$, and this will be the case in such conditions as are likely to occur in designing concrete columns. Then the bending moment may be taken as Wx, and the stress at the base of the column, treating it as homogeneous, will be—

$$f = W\left\{\frac{1}{A} \pm \frac{x}{Z}\right\}$$

very nearly, where A is the whole section of the column and Z the modulus of the section relatively to an axis through the centre of gravity and at right angles to the plane of bending.

---

[*] M. Considère recommends that the distance between the coils of the spiral should not exceed from $\frac{1}{10}$th to $\frac{1}{7}$th of the diameter of the spiral. In the case of piles subjected to longitudinal shock in driving there are special reasons for decreasing the distance between the cross binding near the ends.

In dealing with reinforced columns which are not homogeneous, it is convenient to substitute for the actual section of the column what may be termed the equivalent section, or section of concrete equivalent in resistance to the actual column. If A_c is the area of section of the column (including the area of reinforcement), and a is the area of reinforcement, then the equivalent section is

$$A = A_c + (m-1)a.$$

If h is the depth of the section in the plane of bending, the moment of inertia relatively to the neutral axis can be expressed in the form $I = nAh^2$, and the section modulus in the form $Z = \frac{1}{2}nAh$.

It is desirable in columns that there should be no tension, and generally when the vertical load is considerable there is none. Cases in which the eccentricity is so great that there is tension must be treated by the methods applicable to beams if it is made a condition that the steel carries all the tension. In the following cases it is assumed that there is no tension.

Case I.—Column of Circular Section, Reinforced Symmetrically to the Neutral Axis.—Let m be the ratio E_s/E_c of the coefficients of elasticity of steel and concrete, A_c the cross-section of the column in square inches, a the area of reinforcement in square inches, h the diameter of the column, h_t the distance between the reinforcing bars perpendicular to the neutral axis. Then the equivalent section is

$$A = A_c + (m-1)a$$

and the modulus of the section is

$$Z = \frac{1}{8}A_c h + \frac{1}{2}(m-1)a\frac{h_t^2}{h}.$$

The stress at the edges of the section can then be calculated by the general equation

$$f = W\left(\frac{1}{A} \pm \frac{x}{Z}\right)$$

where x is the eccentricity of the load in inches and W the load in pounds. The greater value of f must not exceed the safe stress stated above.

Case II.—Rectangular Section with Reinforcement Symmetrical to the Neutral Axis.—Using the same notation as in the last case, h being now the depth of the section in the plane of bending, the section modulus is

$$Z = \frac{1}{6}A_c h + \frac{1}{2}(m-1)a\frac{h^2}{h},$$

and stresses are given by the same equation as in the previous case.

Case III.—Column of Circular Section with Reinforcing Bars Arranged in a Circle.—Using the same notation as in Case I., h_t being the diameter of the circle of reinforcing bars, the section modulus is

$$Z = \frac{1}{8}A_c h + \frac{1}{16}(m-1)a\frac{h_t^2}{h},$$

and the stresses are given by the same equation as in Case I.

(c) Long Columns Axially Loaded.

For columns more than 18 diameters in length there is a risk of lateral buckling of the column as a whole. The strength of such columns would be best calculated by Gordon's formula, but there are no experiments on long columns by which to test the values of the constants for a concrete or concrete and steel column. There does not seem, however, to be any probability of serious error if the total load is reduced in a proportion inferred from Gordon's formula to allow for the risk of buckling.

Let, as before, A_c = the section of the column in inches; a = the area of reinforcement. Then $A = A_c + (m-1)a$ is the equivalent section. Let n be the constant in the equation, $I = nAh^2$ and h the least transverse dimension of the column.

Then for a column fixed in direction at both ends, Gordon's formula is

$$\frac{W}{Af} = \frac{1}{1 + \frac{l^2}{cnh^2}} = \frac{1}{1+K}$$

so that the column will carry less than a short column of the same dimensions in the ratio of 1 + K to 1, or, in other words, the column will be safe if calculated as a short column, not for the actual load W, but for a load (1 + K) W.

The constant c has not been determined experimentally for reinforced long columns. But its probable value is—

$$c = \frac{4\pi^2 E_c}{f}$$

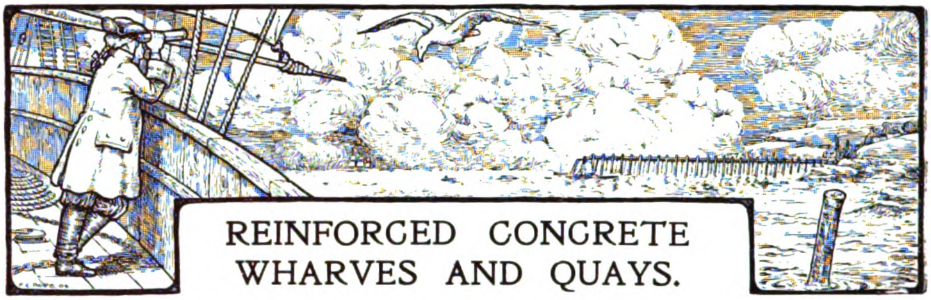
where f is the ultimate crushing stress. Putting $E_c = 2{,}000{,}000$ and $f = 2{,}500$, then $c = 32{,}000$. Looking at the well-understood uncertainty of the rules for long columns, very exact calculation is useless. Some values of n for ordinary types of column are given in Appendix III. Taking these values, the following are the values of 1 + K :—

Values of 1 + K.

$\frac{l}{h}$	*Case I.* n=0·098	*Case II.* n=0·075	*Case III.* n=0·0646
20	1·13	1·17	1·19
25	1·20	1·26	1·30
30	1·29	1·38	1·44

The differences of 1 + K for considerable differences of n are not very great. In any case n can be found by the method in the Appendix with little trouble.

In the case of columns fixed at one end and rounded or unfixed at the others, 2 K must be substituted for K. If the column is rounded at both ends, 4 K must be substituted for K.



REINFORCED CONCRETE WHARVES AND QUAYS.

ARTICLE II.

BY W. NOBLE TWELVETREES, M.I.Mech.E.

We have previously published a series of articles dealing with reinforced concrete bridges by Mr. W. Noble Twelvetrees, and we are now presenting a further short series on the subject of Wharves and Quays, illustrating characteristic examples, both large and small, in which reinforced concrete has been used at home and abroad.

The article in our May issue dealt with examples constructed in France on the Coignet system.—ED.

PARKESTON QUAY EXTENSION, HARWICH.

THIS important work, which will have the effect of doubling the existing accommodation at the Continental station of the Great Eastern Railway Company in Harwich Harbour, was designed by Mr. John Wilson, M.Inst.C.E., the chief engineer to the company, in accordance with the Hennebique system.

Fig. 1 is a block plan showing the existing quay, about 1,200 ft. long, and the station buildings at the right hand, and the new quay, 1,080 ft. long by 51 ft. 10 in. wide, at the left hand. It will be observed that the triangular area of land between the reinforced concrete construction and the present high-water mark of ordinary tides will be reclaimed and used as the site of sheds and sidings in connection with the main line of the Great Eastern Railway. The old portion of the quay will be used as at present for passenger traffic, while the extension is to be equipped specially for dealing with merchandise, for which purpose a range of powerful cranes will be installed in the positions indicated on the plan. The new quay will provide three 320 ft. berths for steamers, and upon it will be erected the sheds necessary for dealing with traffic and buildings for customs purposes. The shed indicated in *Fig.* 1 is designed for use as a locomotive depôt, and will be founded upon a continuous slab of reinforced concrete.

Fig. 2 contains an elevation and a plan of the extension, the former giving some interesting sections of trial borings at three points, where it was found that below the bed of the river a layer of ballast 15 ft. thick occurred at the depth of 44 ft. from quay level overlying a firm stratum of yellow clay, in which the foundation piles are being driven in the positions indicated on the plan.

The total number of foundation piles required for the construction of the quay is 439, including two piles in each of the piers indicated by shaded circular areas along the river front.

Sheet piles to the number of about 870 are being driven on the landward side, as represented in *Fig.* 2 by a thick black line.

The present bed of the river is almost exposed at low water of ordinary spring tides, but by dredging the depth of water will be increased to 20 ft. at low tide, and 32 ft. at high tide. Various levels of the foreshore and river are shown in sections CC, DD, and EE given in *Fig.* 3, two of these drawings also indicating the position of the locomotive shed.

Fig. 4 is an elevation including two bays of the quay. The piers supporting the main beams along the front are of cylindrical form, and of 4 ft. 6 in. diameter. They are spaced 25 ft. apart, centre to centre, and extend down to the stratum of ballast, and, as described below, form continuations of foundation piles driven well into the clay. It will be observed that the dimensions of the beams are increased considerably at each end so as to give ample rigidity, and that horizontal beams, or walings, are connected with the piers at the distance of 12 ft. 7 in. below quay level. Timber fender piles are driven in front of each reinforced concrete pier for the protection of vessels coming alongside.

Further particulars of the construction will be found in *Figs.* 5 and 6. The first of these is a section on the line EF in *Fig.* 6, and indicates the depth to which the main piles are driven. These members extend from the walings, at a distance of 14 ft. 7 in. below quay level, to the depth of 32 ft. 6 in. at the west end, and 38 ft. at the east end of the structure. As shown in *Fig.* 6, containing sections on the lines AB and CD (*Fig.* 5), all the independent piles are of square cross section, and those driven in pairs of octagonal section, the dimensions being 14 in. by 14 in. in each case.

The heads of the rectangular piles are trimmed off level, and the two front rows are connected transversely and longitudinally, as shown in *Figs.* 5 and 6 by horizontal members *a* and *b* with the width of 12 in. and the depth of 14 in. Those in the row at the back of the quay are connected by sheet piles driven firmly into the stratum of ballast to form a watertight wall, which is capped by the horizontal members shown in section by *Fig.* 5. Beyond the line of the quay decking a continuous counterfort is formed by a fourth row of 14-in. square rectangular piles connected longitudinally by walings 12 in. wide by 15 in. deep. These piles are connected with the piles in the next row by a reinforced concrete slab 7 in. thick, stiffened by ribs 7 in. wide by 13 in. deep below the under surface of the slab and spaced at intervals of 4 ft. 2 in. apart centre to centre.

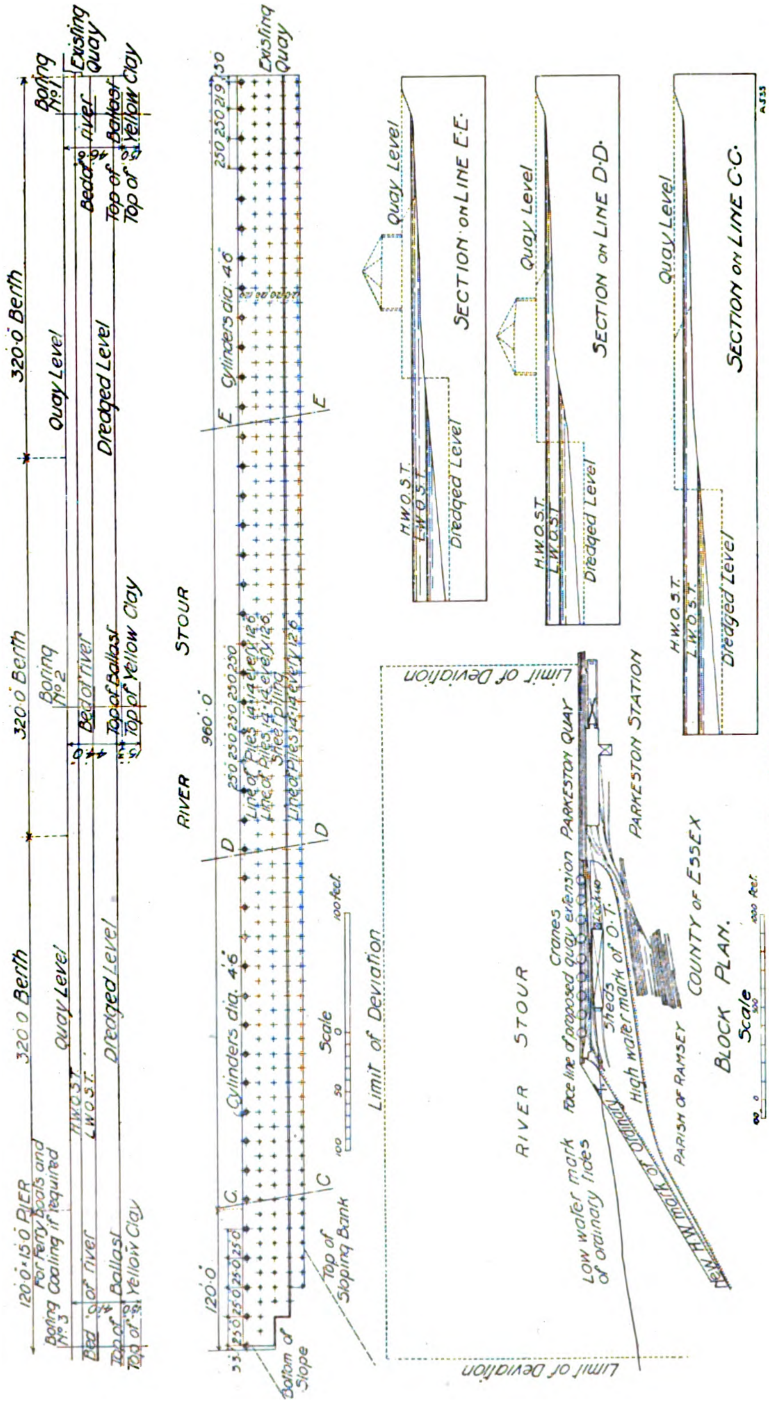
All the rectangular piles in the quay proper are prolonged in the form of columns for supporting the deck beams and slab, the main longitudinal beams measuring 12 in. wide by 15 in. deep, and the transverse beams 7 in. wide by 15 in. deep, these dimensions being exclusive of the deck slab, which is 6 in. thick.

For the purpose of increasing the rigidity of the construction, diagonal struts are built between the columns as represented in *Fig.* 5, but as examination of the section CD in *Fig.* 6 will show, the direction of the struts is changed at every alternate series of columns, thus giving adequate resistance to forces exerted at quay level or near the junction of the columns with the supporting piles. Further the continuous counterfort along the back of the quay is stiffened by diagonal struts, 12 in. wide by 14 in. deep, between each pile and the corresponding column.

Reference to *Fig.* 5 shows that in addition to the platform between the outer piles of the counterfort and the piles of the quay proper, a curtain wall is built above the sheet piling up to the main longitudinal deck beam. The object of these two slabs is to utilise the weight of the earth filling above the platform, so as to counterbalance part of the pressure against the walls, thereby increasing the stability of the construction, and at the same time reducing the stresses in the piles, columns, and bracing.

So far only incidental reference has been made to the main piles and piers along the front of the quay. The piles themselves are driven exactly like the independent piles in the remainder of the work, but in pairs prolonged in the form of columns. A cylindrical casing of reinforced concrete with the exterior diameter of 4 ft. 6 in. is applied outside each pair of piles, the bottom of the cylinder being below the bed of the river and the top at quay level. When the cylinder has been adjusted in position, reinforcement is placed around the two rectangular piles, and the interior space is filled in with concrete, thus converting the whole into a massive pier. The cylinders are moulded in advance, the inner surface being irregular so as to insure a good bond between the old and new concrete, and lateral reinforcement is provided in the form of ties projecting from the inside of the cylinders.

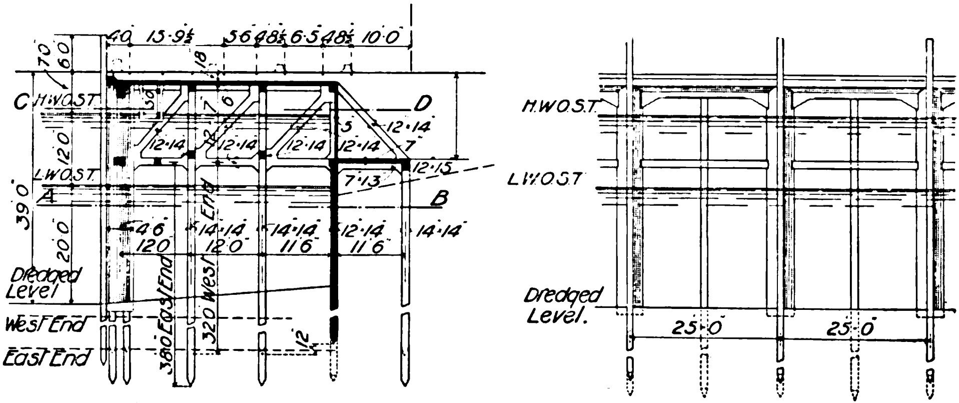
At Parkeston Quay the piers along the river front are connec-



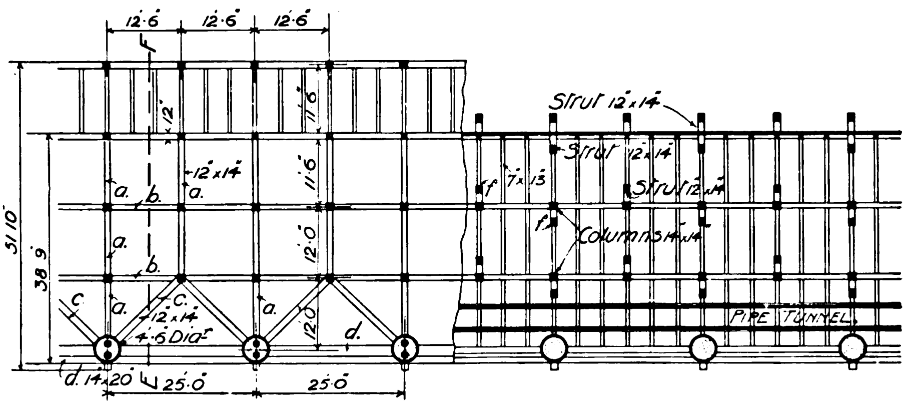
Figs. 1, 2 and 3. Parkeston Quay Extension, Harwich.

ted horizontally by the two lines of beams represented in *Figs.* 4 to 6, these members being 14 in. wide by 20 in. deep, and, as before mentioned, the beams in the upper row are strengthened by knee bracket extensions at the ends.

Between each pier and the rectangular column immediately behind it the bracing consists of a horizontal member, a diagonal strut 12 in. wide by 14 in. deep, and horizontal members of the same dimensions extending from each pier to the two intermediate columns in the front row. All the members in question are built into the piers, and the main bars of the reinforcement pass from one member to another so as to insure adequate resistance at the various joints, where the monolithic character of the concrete work provides for the rigidity of the construction.



SECTION ON LINE E·F FRONT ELEVATION.



SECTION ON LINE A·B· SECTION ON LINE C·D·

Figs. 4, 5 and 6. Parkeston Quay Extension, Harwich.

Pits for capstans, foundations for bollards, and openings for drainage are formed at numerous points along the quay, and a subway for hydraulic water mains and other conduits runs behind the front piers as shown in section by *Fig.* 5 and in plan by *Fig.* 6, the positions of the capstans, etc., being shown in the former drawing.

The deck slab of the quay connecting the longitudinal and transverse beams is 6 in. thick, and is finished at the front and back by a raised curb for the purpose of holding up the ballast on which the railway lines and crane roads will be laid. There are to be three railway sidings on the new quay, in addition to others in the sheds and on the area of land reclaimed. Near the front of the quay a track of 15 ft. 9½ in. gauge will be laid for portal and semi-portal cranes.

The quay is designed for the dead superload of 4 cwt. per square foot, the rolling load of 18 tons per rail of the crane track on two wheels 16 ft. apart; and the rolling loads of 40 tons on 10 ft. spans, 45 tons on 15 ft. spans, 56 tons on 20 ft. spans, and 66 tons on 25 ft. spans beneath the railway lines.

In the sheds the specified rolling load of 10 tons on two wheels 7 ft. apart will be carried by the general foundation sill of reinforced concrete to be laid on the earth filling at the back of the new quay.

To enable readers to form a more complete idea of the construction embodied in the Parkeston Quay extension we reproduce in *Fig.* 7 one of the working drawings, which shows full details of the reinforcement in the piles, piers, walings, bracing, deck beams, and deck slab.

It should be noticed that all the piles terminate at a level just below the horizontal members constituting the walings. After having been driven, the piles actually extend for a short distance above this level, but the concrete is then stripped off, leaving the various bars of the reinforcement for incorporation in the columns and bracing afterwards built to form the superstructure of the quay.

The piles are shown in elevation, and for this reason the longitudinal bars are indicated by broken lines, while the lateral ties, which, in view of the results obtained by the investigations of M. Considère, may justly be regarded as the characteristic reinforcement of members subject to axial load, are not shown at all. The disposition of these ties, however, is very similar to that of the ties in the columns above. The horizontal beams or walings are designed to act as struts, and not as beams, using the latter term in its restricted sense. Therefore the reinforcement is proportioned and disposed chiefly for withstanding axial pressure, the longitudinal bars being of cross sectional area sufficient to resist such secondary stresses as may be developed in consequence of flexure. The diagonal members of the bracing are reinforced in a precisely similar manner, although the dimensions of the bars are varied in accordance with the calculated strains for each member.

Comparing the design of the horizontal deck beams and the vertical beams constituting stiffening ribs for the curtain wall at the back of the quay with that of the horizontal, vertical and diagonal members intended to resist axial loads or pressures, we see at once the essential difference between the two general types of construction. The reinforcement of the beams consists of straight and bent bars disposed so as to withstand tensile stresses to the best possible advantage. This is the primary duty of beam reinforcement, but the transverse stirrups play an important part by taking care of shearing stresses, or, more correctly, tension on diagonal planes.

In the section on line KK the vertical and transverse reinforcement of the piers at the front of the quay is clearly shown, and the section on line JJ illustrates the manner in which the bars of the bracing are extended and anchored into the concrete of the piers, a detail of the construction that is also illustrated in the general section. Equally satisfactory provision is made for connecting the bracing with the piles and rectangular columns, as represented by the general vertical section and the horizontal section entitled "Junction of bracing and column." The section on line LL represents the method of connecting the upper end of a column with the main and secondary beams of the decking. In other respects *Fig.* 7 speaks for itself.

Work was commenced on the quay extension in November, 1906, and such rapid progress has been made that the main portion of the reinforced concrete construction is now nearing completion. The total cost of the quay, auxiliary works, and dredging is more than £80,000, and in view of the prevailing prices of other structural materials, and the cost which they involve in the way of preparation and erection, the writer feels perfectly justified in stating the opinion that the Great Eastern Railway Company will save from 12 to 15 per cent. on the total cost by the adoption of reinforced concrete in this particular case, besides the heavy annual upkeep inseparable from the use of steel or timber structures of the kind, and which has been entirely obviated by the use of reinforced concrete.

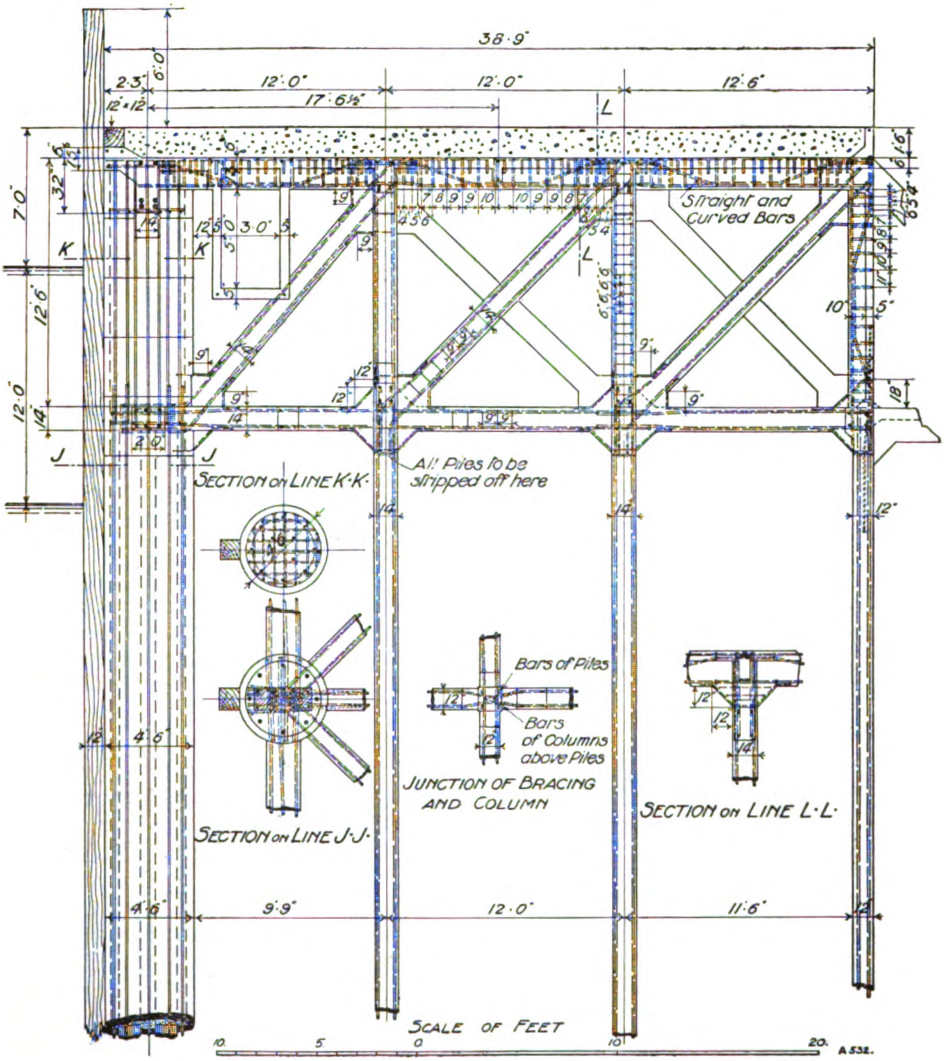


Fig. 7. Parkeston Quay Extension, Harwich.

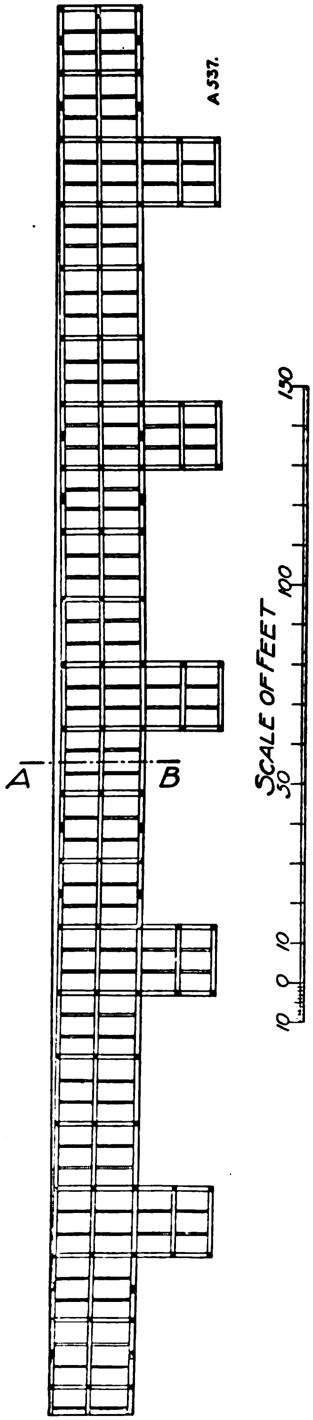


Fig. 8 Dunston Jetty, Newcastle-on-Tyne.

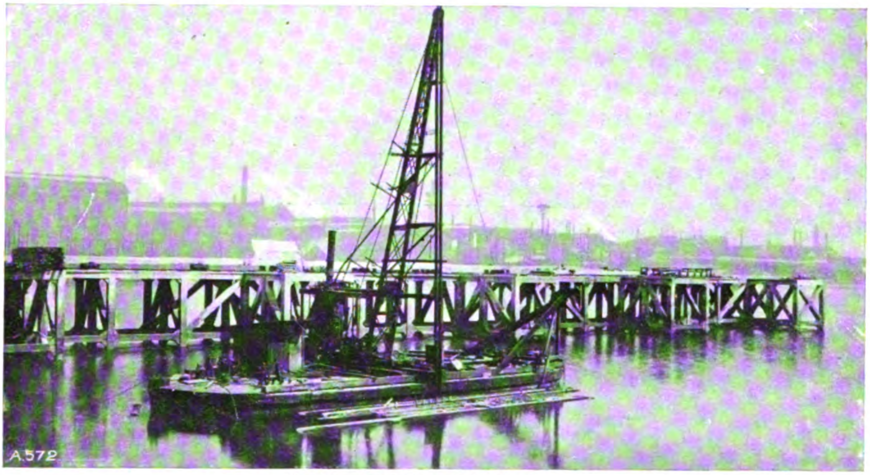
DUNSTON JETTY, NEWCASTLE-ON-TYNE.

When the reinforced concrete flour mills, granary, and grain-cleaning tower of the Wholesale Co-operative Society were built at Dunston, a jetty or landing stage was constructed on the southern bank of the River Tyne immediately in front of the buildings in question. All these structures, exemplifying varied applications of reinforced concrete, were designed by Mr. F. E. L. Harris, A.R.I.B.A., of Manchester, in accordance with the Hennebique system.

Owing to the rapid growth of the Society's business in the Newcastle district it was decided a year or two back to erect a series of cylindrical grain silos on the site between the flour mill and the original jetty. It should be added that the new jetty was completed last year, and that the grain silos are at the present time in course of construction. We mention these facts merely to give the reader an opportunity of realising more clearly the exact nature and purpose of the jetty.

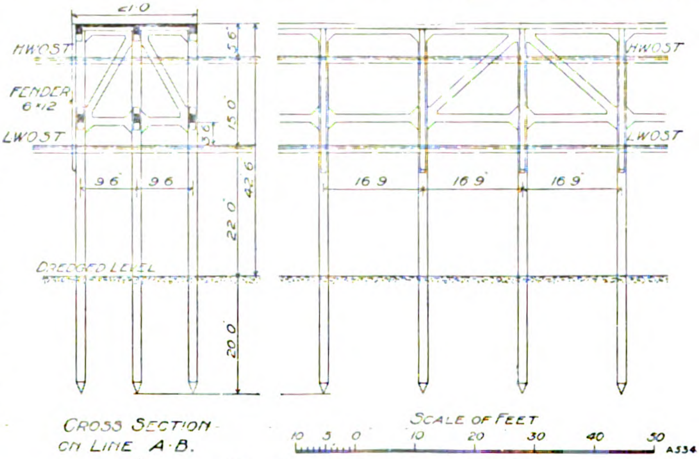
It was at first intended that the jetty extension should be 270 ft. long by 21 ft. wide, but the directors afterwards decided to increase the length to 330 ft., leaving the width unaltered, presumably with the object of keeping down expenditure. The professional advisers of the society recommended that the width should be increased to 40 ft. with the object of adding to the stability of the work, and of providing more adequate space for loading and unloading vessels. They proposed further that the jettty should be designed suitably for reclamation of the area between the extension and the old quay wall. These recommendations were not accepted, but as a compromise five counterforts in the form of spurs were built at the back of the jetty, which increase the stability of the construction, and at the same time provide a useful addition to the deck area. *Fig.* 8 is a general plan of the new jetty showing the five counterforts. Briefly described, the work consists of twenty-one bays, measuring 16 ft. 9 in. by 19 ft., one part bay of 7 ft. by 19 ft. at the left hand end, and five projecting spurs A of 16 ft. 9 in. by 19 ft. on the landward side, all these dimensions being taken from centre to centre of the piles and columns. Each complete bay is founded on six Mouchel's hollow-diaphragm piles, with the average length of 45 ft., connected by walngs, and supporting the superstructure formed of columns braced diagonally, and connected at the top by longitudinal and transverse beams.

It is not necessary to occupy space by detailed particulars and drawings of the special form of pile now in question, as these have been given in a previous issue of CONCRETE AND CONSTRUCTIONAL ENGINEERING.* As there pointed out, one advantage of hollow pile construction is the reduction of weight, by reason of which handling and transport are specially facilitated. But another important advantage possessed by hollow piles is to be found in the fact that for a given weight of material the resistance of a hollow section is far greater than that of a solid section. Consequently the concrete and the reinforcement are applied most economically.



Dunston Jetty, Newcastle-on-Tyne.

Fig. 9 is a cross section of the jetty on the line AB (*Fig.* 8), showing that the piles were driven to the depth of 20 ft. below the level to which the surface of the river bed has been dredged. The piles extend about 25 ft. above the dredged level, and after having been driven they were cut to one uniform height and the concrete stripped down for incorporation of the reinforcement with that of the walings, columns, and column bracing. All the piles and columns have the transverse dimensions of 18 in. by 18 in.; the longitudinal and transverse walings are 14 in. wide by 16 in. deep. The joints between the piles, columns, and bracing at the height of 3 ft. 6 in. above low water



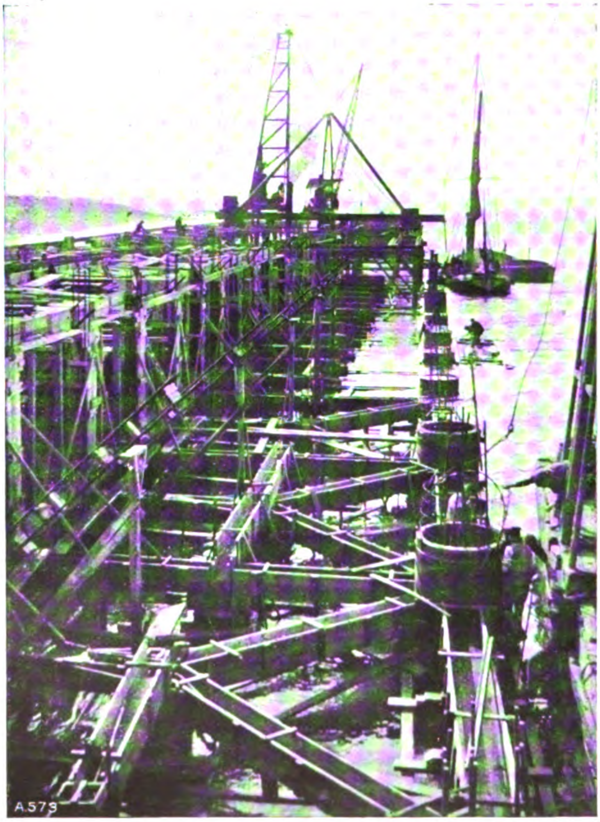
Figs. 9 and 10.—Dunston Jetty, Newcastle-on-Tyne.

---

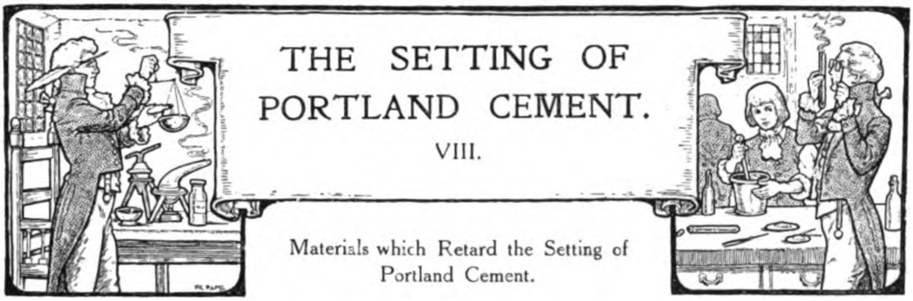
* "Reinforced Concrete Piles in Tidal Waters," Vol. 1, No. 2, p. 97.

level are similar to those shown in detail by *Fig.* 7, and, as may by seen by *Figs.* 9 and 10, the rigidity of the connections is amply secured by filling up all angles with concrete.

In addition to transverse diagonal bracing, longitudinal members of the same type are included at intervals, two of these being represented in the part elevation (*Fig.* 10). All the diagonal members of the bracing are 14 in. wide by 16 in. deep, and together with the walings are designed for withstanding axial pressures. The upper ends of the columns are connected by longitudinal and transverse main beams (see *Figs.* 9 and 10) and a continuous deck slab. The longitudinal beams at the front and back of the jetty measure 16 in. square, and those along the centre are 14 in. wide by 16 in. deep, the transverse beams are 14 in. wide by 18 in. deep, the joints in every case being stiffened by knee bracing at the angles. In addition to the main transverse beams connecting the three rows of piles, secondary beams 5 in. wide by 8 in. deep extend from front to back of the jetty, dividing each bay of the jetty into three panels 9 ft. 6 in. long by 5 ft. 7 in. wide. Over the entire system of beams is the continuous deck slab 4 in. thick.



Parkestone Quay Extension, Harwich.



THE SETTING OF PORTLAND CEMENT.

VIII.

Materials which Retard the Setting of Portland Cement.

By R. C. CARPENTER (U.S.A.).

To all engaged in constructional engineering, and more particularly in the application of concrete and reinforced concrete, the question of the setting of Portland cement is one of the utmost importance. Having regard to this, arrangements have been made by which a series of articles will be presented by well-known authorities at home and abroad, dealing with the question in its chemical and physical aspects, and these various articles will finally be summarised with the view of presenting the more important facts and the consensus of opinion. The attention accorded to the earlier articles has encouraged us to extend our list of contributors on this subject to the leading authorities of other countries. Correspondence is invited, as a free discussion of the various arguments put forward will be welcome to all who have this subject at heart.

Dr. Carpenter's paper gives us definite information on a point which we understand has always been a cause of difficulty to the Civil Engineer or user of cement—i.e., the property which Portland Cement possesses of changing its setting time in accordance with varying atmospheric conditions and other causes; particularly noticeable with cement to which gypsum has been added for purposes of retarding the setting time, which was apt on storage to return to its quick-setting condition. The results of experiments given by Dr. Carpenter would appear to confirm the experience of many as to what actually takes place when gypsumised cement is stored, more particularly in bags. As we have indicated before, this reverse action is prevented if the cement has also been subjected to the Bamber hydrating process during grinding, now so largely adopted by the Associated Portland Cement Manufacturers and others.—ED.

PORTLAND cement when mixed with water has two properties pertaining to the hardening process which are essentially similar in many respects, but differ in quality and characteristics to such an extent that they have different names. The one property that marks the preliminary process during which the mortar becomes pasty and brittle is termed the "setting"; the other, which is slow, long-continued, and permanent, the "hardening." In accordance with investigations of Le Chatelier, the "setting" is due to the formation of saturated solution of alumina compounds, as aluminate of lime and similar compounds, from which crystals are deposited with great rapidity in the case of rapid-setting cements, and at a less rapid rate with those which set slowly. The hardening process which takes place later is largely due to the formation of crystals of silica compounds, as trisilicate of lime, which are interlaced with crystals of other compositions.

In many instances the setting, which is the initial process of hardening, takes place so rapidly as to present practical difficulties in the proper gauging and use of the cement. To overcome these difficulties it has been customary for many years in the manufacture of Portland cement to mix with the cement some material which would retard the formation of the crystals of aluminate of lime and similar compounds, and thus regulate the time of setting.

For this purpose, gypsum (sulphate of lime, $CaSO_4$) has been principally used. The effect of adding gypsum is only temporary, provided the cement is exposed to the air, and for that reason other materials have been sought for. The present article gives a brief description of some experiments made in the Mechanical Laboratory in 1904, by Walter H. Kniskern and William L. Gass, for the purpose of determining the regulating power on the setting of cement of gypsum and chloride of calcium ($CaCl_2$).

For the purposes of the experiment, one of the large Portland cement works supplied us with clinker which had not been treated, and which, in its normal condition, made a remarkably quick-setting cement. This clinker was ground in a pebble mill owned by the Laboratory, under conditions which permitted the addition of the various materials to be tested.

The following shows in tabular form the results of adding different amounts of gypsum, the gypsum being proportioned by weight, as indicated in the first column of the table. In these experiments the time of initial set is taken in every case as the time when a pat of the cement made by mixing with the percentage of water shown would bear a rod with diameter of $\frac{1}{12}$ in., carrying a weight of $\frac{1}{4}$ lb. The time of final set is taken as that time which has elapsed since mixing, when the pat will bear a rod $\frac{1}{24}$ in. in diameter, carrying a weight of 1 lb. This method of determining the set, although commonly used, depends to some little extent upon the judgment of the operator, and, as would naturally be expected, gives results which are somewhat irregular, although sufficiently accurate for purposes of comparison.

The results of the trials referred to with gypsum show that 1½ per cent. produce the maximum effect in retarding the set, and that for the special samples tested no beneficial results were obtained by the use of a large amount.

The following table shows the retardation of the set due to using different quantities of gypsum :—

Per Cent. CaSO	Per Cent. Water.	Initial Set Min.	Final Set Min.	Per Cent. CaSO	Per Cent. Water.	Initial Set Min.	Final Set Min.
0.0	29.8	2.0	52	4.0	24.2	28	45
0.5	27.6	6	87	4.5	25.4	22	40
1.5	22.1	80	157	5.0	25.4	27	59
2.0	22.1	24	114	5.5	25.4	20	78
2.5	23.7	29	79	6.0	24.2	19	37
3.0	22.1	30	69	6.5	23.7	22	40
3.5	22.1	27	72	7.0	25.4	18	59

Although the experiments above show that a maximum retarding effect was produced by the sulphate of lime when less than 2 per cent. was ground with the clinker, it is quite certain from previous experiments that, with Portland cement of different composition, or having been burned differently, more gypsum would have been required for maximum effect.

Thus, E. Candlot, in his work, "Ciments et Chaux Hydrauliques," gives the results of adding different quantities of gypsum to three specimens of cement. These show in each case an increase in retardation up to 2 per cent., and in one instance up to 4 per cent. His experiments were as follows :—

Quantity of Gypsum Added, per Cent.	Time of Setting in Fresh Water. (1.)		(2.)		(3.)	
	Initial H. M.	Final H. M.	Initial H. M.	Final H. M.	Initial H. M.	Final H. M.
0	0 7	0 22	0 7	0 15	0 2	0 5
·5	0 50	2 43	4 10	0 17	0 2	0 5
1.00	2 40	4 50	3 50	5 0	1 30	2 35
1.5	2 57	5 17	3 50	5 0	3 20	5 15
2.0	3 0	5 20	4 20	6 45	4 0	7 0
3.0	3 0	6 40	3 45	7 0	5 0	7 0
4.0	3 30	7 0	5 0	7 0	5 0	7 0

In the table it is noted that the extremely rapid-setting cement, No. 3, had a maximum retardation when 2 per cent. of gypsum was added; when a larger amount was added there was no effect on the time of setting. With the slowest-setting specimen the retardation increased as the amount of gypsum was increased to 4 per cent., although the increase was slight after 3 per cent. had been added. The experiments show no decrease in time of the final set with increase in the amount of gypsum up to 4 per cent.

As showing the temporary effect of gypsum in regulating the set, the following experiments are quoted from Candlot when cement is mixed with fresh water :—

INFLUENCE OF TIME ON THE SET OF CEMENTS MIXED WITH SULPHATE OF LIME (GYPSUM).

Per cent. of Gypsum.	Time on Trial.	Initial H.	Initial M.	Final H.	Final M.
3	Day of mixture	1	0	7	0
3	4 days after	0	5	2	15
3	7 days after	0	5	0	20
3	11 days after	0	8	0	30
3	15 days after	0	5	0	30
3	19 days after	0	7	0	35
3	24 days after	0	5	0	25
3	32 days after	0	10	0	30
3	41 days after	0	45	5	30
2	Day of Mixture	5	0	19	0
2	12 days after	4	40	14	0
2	21 days after	0	18	0	50
1	Day of mixture	5	30	8	30
1	8 days after	0	18	2	30
1	15 days after	0	11	0	20
1	Day of mixture	6	0	9	30
1	8 days after	4	30	8	0
1	15 days after	0	15	0	30
1	30 days after	0	0	7	00

The above tests were made when the cement was exposed to the action of the air. It is noted that in two cases a long time test showed a return of the retarding action of the gypsum on the cement, although it is not certain that this might not have been due to some other cause.

Candlot kept the cement mixed with 2 per cent. of gypsum, in a very close bin, with the following results :—

	Time of set Initial H.	Time of set Initial M.	Time of set Final H.	Time of set Final M.
Day of mixture	3	0	6	25
After one month	2	50	5	0
After two months	1	30	7	0
After five months	0	10	0	18

The addition of small quantities of sulphate of lime increases the strength, except when the cement is immersed in sea-water and the proportion of sulphate is greater than 2 per cent., in which case the briquettes soon show traces of alteration, and in time completely disintegrate.

The experiments quoted are conclusive in showing that there is little or no advantage gained in adding more sulphate of lime than 2 per cent., and I believe that it would not be an unreasonable requirement in specifications to call for such a limitation.

Experiments made by Candlot and verified in the Mechanical Laboratory of Sibley College indicate that an addition of 2 to 4 per cent. of slacked lime or hydrate of lime added to a cement containing a small percentage of gypsum, which has through the influence of time lost its effect in retarding the cement, will restore the slow-setting properties.*

From 2 to 5 per cent. of lime hydrate will be found useful for retarding the setting of cement to which gypsum has been added, but which has lost the effect. The additional lime does not detract from the strength, as, in the case of the last-named cement, its initial strength, neat, was as follows :—24 hours, 360 lb.; 1 week, 757 lb.; 1 month, 871 lb.

The addition of hydrate of lime without the addition of the sulphate of lime seems to have little or no effect on the time of setting, as shown by experiments made by Kniskern and Gass.

	Time of set Initial H.	Time of set Initial M.	Time of set Final H.	Time of set Final M.
*Cement containing 2 per cent. of gypsum	0	20	2	30
Same cement to which has been added 2 per cent. of lime	6	0	10	0
Cement containing 1 per cent. of gypsum	0	10	0	20
Same cement with 2 per cent. of lime added	1	0	8	0
Test made in Sibley College Laboratory of sample				
Containing 2 per cent. of sulphate	0	12	0	15
Same cement with 5 per cent. of lime hydrate added	2	0	5	0

INFLUENCE OF CHLORIDE OF CALCIUM IN THE SETTING AND HARDENING OF PORTLAND CEMENT MORTARS.

The investigations of E. Candlot, as recorded in his work on "Ciments et Chaux Hydrauliques," show that when Portland cement is gauged with a feeble solution of chloride of calcium, it has the effect of greatly retarding the time of setting; but when the Portland cement is gauged with a concentrated solution of chloride of calcium—as, for instance, 100 to 400 grammes per litre—it acts in a contrary manner, and tends to increase the rapidity of setting. Candlot gives the following table as showing the results of his experiments :—

TIME OF SETTING OF NEAT CEMENT.

Solution of $CaCl_2$ Grs. per Litre	(1.)		(2.)		(3.)		(4.)	
	H.	M.	H.	M.	H.	M.	H.	M.
2	0	5	1	5	8	0	1	34
5	0	8	10	0	12	0	2	0
10	8	18	10	0	14	0	5	50
20	1	0	12	0	10	30	8	0
40	4	35	8	0	6	30	8	35
60	3	20	6	0	4	0	6	0
100	0	3	0	20	0	30	3	30
200	0	3	0	9	0	5	0	25
300	0	2	0	8	0	3	0	5

Candlot explains the action of the chloride of calcium by showing that a feeble solution of chloride of calcium tends to retard the solution of those alumina salts which, on crystallising, cause the material to set. The feeble solutions have no appreciable influence on cements which do not contain alumina. In case the concentrated solution of chloride of calcium is used for gauging, the aluminate of lime is attacked very energetically, which thus causes a very rapid set, as indicated by the experiments given above.

Candlot also states that a feeble solution of chloride of calcium acts very rapidly in hydrating or slaking lime, and quotes an experiment showing that a cement containing an excess of lime gauged with pure water swelled and disintegrated, because of the tardy expansion of the free lime, while the same cement gauged with a solution of chloride of calcium containing 30 to 60 grammes per litre gave no evidence of swelling, because the free lime was slaked completely and perfectly before the beginning of the initial set. The folllowing experiment from Candlot shows the action of chloride of calcium in accelerating the slaking of lime. This action is shown in the experiment by the rapid rise of temperature caused by the slaking action when the lime is mixed with the solution of chloride of calcium :—

	TEMPERATURE, DEGREE C.		
Time.	Distilled water.	30 grammes $CaCl_2$ per litre.	60 grammes $CaCl_2$ per litre.
Initial	18	18	18
5 min.	19	19	19
10 min.	20	21	24
15 min.	25	35	90
20 min.	25	90	98
25 min.	25	98	99
30 min.	20	90	95

The lime was completely slaked or hydrated in 30 minutes when gauged with either solution of chloride of calcium, but required about 48 hours before it was completely slaked when the distilled water was used.

Candlot has also pointed out that a concentrated solution of chloride of calcium tends to harden Portland cement very rapidly, and causes the tensile strength to reach a maximum quickly, the cement made in that way at the end of the year being, however, perfectly good and sound.

Messrs. Kniskern and Gass, in the Sibley Laboratory, ground different percentages of chloride of calcium with cement clinker, and afterwards made pats, using in each case simply enough water to give the material its normal consistency for this purpose. Their results show that the chloride of calcium had great effect in retarding the time of setting, and exerted the greatest effect when about one-half of 1 per cent. by weight of the chloride of calcium was employed. On account of the water required, 1 per cent. of the chloride of calcium would correspond approximately to gauging with a solution of 30 grammes per litre in the previous experiments quoted :—

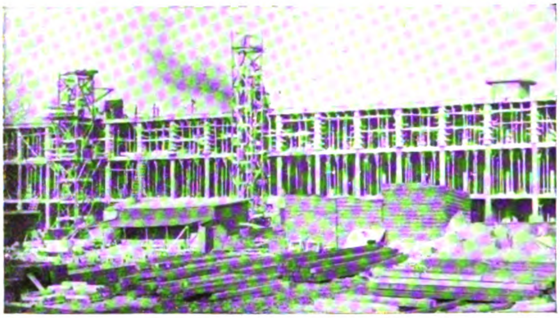
CaCl$_2$ Ground Dry with the Clinker.

Per Cent. of CaCl$_2$	Per Cent. of Water.	Initial Set.	Final Set.
0.0	29.8	2.0*m*.	52*m*.
0.5	34.1	115	274
1.0	29.8	160	272
1.5	26.4	167	234
2.0	25.4	127	212
2.5	26.4	103	180
3.0	26.4	45	182
3.5	26.4	97	185
4.5	28.6	63	150
5.0	29.8	73	160
5.5	29.8	76	84
6.0	29.8	68	145

The experiments quoted indicate that chloride of calcium added in small percentages, either to the ground clinker as a powder or mixed with the water for gauging, has an important effect in extending the time of setting of Portland cement, and, so far as the investigations which are accessible show, it does not have any detrimental effect on the permanent strength and hardness.

Chloride of calcium is a deliquescent material which rapidly absorbs moisture, and it is possible that if ground dry with the Portland cement clinker, even to the amount of ½ per cent., it would cause the material to gather dampness, and thus have a bad effect. The chloride of calcium solution can be added readily by adding it to the water used in gauging, since it dissolves with extreme rapidity. The experiments indicate that the set can be controlled by using less than ½ per cent., which would be something less than two pounds to the barrel of Portland cement. Investigations are still necessary for determining whether the effect of chloride of calcium added to the cement before grinding is permanent in its effects, and whether, if ground with the cement clinker, it would exert any detrimental effect.

Rapid Factory Construction in Reinforced Concrete



A View Taken Forty-one Days after Work began. (Nov. 13th).

There can be no doubt as to the great economy of reinforced concrete for the construction of factories, on simple or so-called straightforward plans. It may, however, not be quite fully realised that for buildings where suitable materials are available, the element of speed means great economy and considerable convenience to factory owners using reinforced concrete.

Below we print, by the courtesy of Mr. Robert W. Lesley, of the "Cement Age," an interesting report of a factory of considerable dimensions, which was rapidly re-erected after a fire.—ED.

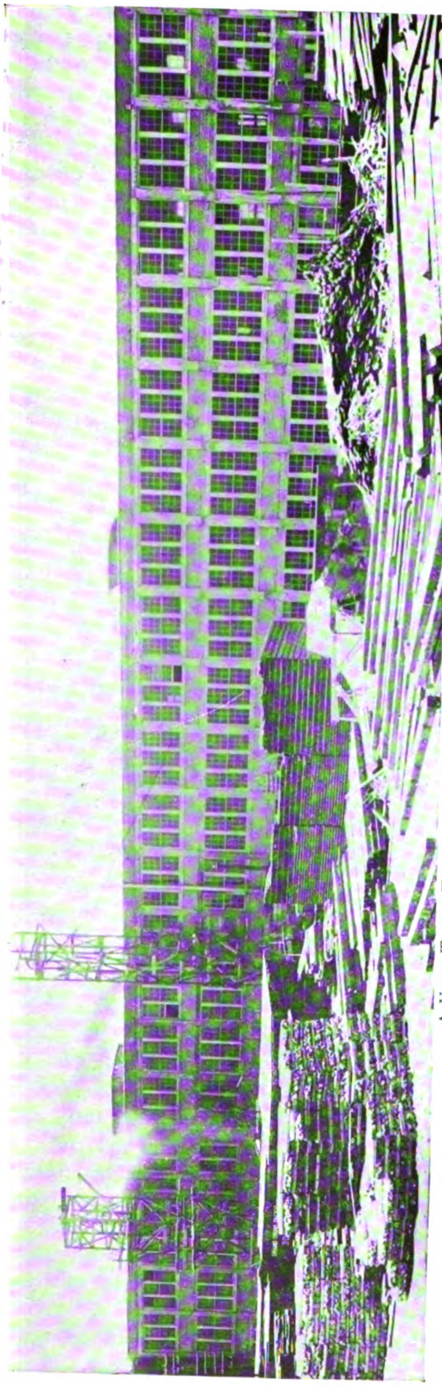
The Anderson Carriage Co.'s factory, of Detroit, U.S.A., having been destroyed by fire on September 9th last, the owners decided upon reconstructing it in reinforced concrete.

The designs were prepared by the company's architect, Mr. George W. Mason, and the contract was accorded on September 26th to the Concrete, Steel, and Tile Construction Co., of Detroit, who make a speciality of using the Kahn bar for reinforcement.

Possession of the site was given on October 2nd, and the contract, which was signed on October 4th, required the completion of the north half of the building within forty working days, and the completion of the remainder of the building within an additional forty days. These time limits are of particular interest, having regard to the fact that the site covered by the building measures 303 ft. 4 in. by 90 ft. 4 in., that the building is of three stories, that all vertical supports and beams are of reinforced concrete, that the floors are a combination of reinforced concrete and terra cotta, and the wall faces comprise brick walls supported at the floor levels by reinforced concrete beams.

The time, however, was kept to, regardless of the fact that five working days were lost through bad weather, and the owners had possession of half the building within 2½ months of the fire, the first 3½ weeks of which were occupied with the preparation of the plans and the clearing of the site.

The work was started with a force of twenty men, and within nine working days the north half of the second floor, supported on reinforced concrete columns, was in place and work started on the north half of the third floor, and the column supporting the south half of the second floor. The staff was gradually increased to an average of 200 men. After a further 10 days of work the north half of the third floor and the south half of the second floor were up and the framing for columns and roof in the north wing and columns and third floor in the south half started. The third floor and the north half of the roof construction were finished by the 23rd of October, and the south half of the roof was laid and the framing and platform for a 20,000 gallon tank support finished on November 7th. In the meantime the grading of the ground floor had been started and about two-thirds



A View Taken Twenty-nine Days after Contract was signed (Nov. 2nd).

of the concrete floor laid on the underlying cinder bed.

The concrete employed in the construction was of the following mixtures: footing concrete 1 : 3 : 5 applied in 6-in. layers. Ground floor concrete slab, one 4-in. layer of concrete composed of 1 part cement and 6 parts of gravel and sand properly mixed with a finishing course 1 in. thick composed of 1 part cement and 2 parts of sand.

The concrete used in the second and third floor construction, as well as in the roof and tank-support, was composed of 1 part cement and 5 parts of sand and gravel with the upper ½ in. a finishing course composed of 1 part cement and 2 parts of sand. Door sills were of 7 by 12 in. solid concrete with Kahn lintel bars for reinforcement.

The roof was waterproofed by a layer of hot pitch, on which were laid 4 layers of tarred felt at 15 lbs. per sq., topped off with a finish of hot pitch, thoroughly covered with fine screened dry gravel.

CONSTRUCTIONAL FEATURES.

The building is divided longitudinally into 20 bays 14 ft. each and one bay of 15 ft., all centre to centre of columns, transversely into 5 bays of approximately 18 ft. each centre to centre of columns. The columns rest on spread foundations 4 ft. sq. at the bottom and 4 ft. 6 in. below the finished first floor level and imposing a pressure of 2½ tons per sq. ft. on the ground. The footings, with the exception of those supporting the columns, which carry the two 20,000 gallons tanks above the roof level, are not reinforced, the latter footings having ¾-in. by 2-in. Kahn bars running both ways. These footings are from 5 ft. to 6 ft. 9 in. square. The first floor, as mentioned before, consists of a 4-in. solid concrete slab with a 1-in. finish layer, and is not reinforced, resting directly on the graded layer of 6 in. of tamped cinders.

The second and third floors are designed for a uniform live load of 65 lb.

per sq. ft., the roof being built for a uniform live load of 40 lbs. per sq. ft. The second and third floors are composed of 6-in. tile separated by concrete joists 4 in. wide with ½-in. by 1½-in. Kahn reinforcing bars, a 2-in. layer of concrete over the whole of the floor area finishing the floor construction. The interior columns supporting the second floor are, with the exception of the tank-supporting ones, 14 in. sq., the wall columns are reinforced by 4¾ in. by 2 in. sheared Kahn column bars. The wall columns have grooves in two sides to give better mechanical bond between the columns and the walls, the bricks being set and mortared into these recesses. The interior columns supporting the third floor, with the exception again of the tank-supporting columns, are 12 in. sq., the wall columns being again 16 in. by 16 in. and 20 in. by 20 in. cross section and all reinforced by four ¾-in. by 2-in. bars.

The splice between these bars and the ones supporting the second floor as well as between bars in the columns supporting the third floor, and those carrying the roof, was provided for by pipe sleeves of a diameter which brought the sheared ends of the steel bars in direct bearing upon one another. The floor beams, running cross ways between the columns, are mainly of 10 by 20-in. section with 2 1-in. by 3-in. bars in each, with sheared diagonals 24 in. long bent up at an angle of 45 degrees. By keeping the tile 4 in. from the edge of the beams a solid concrete tee is provided which increases the cross-section of the beam and makes a strong joint between the tile floor and the beam proper.

A View Showing Rear of Plant. (Nov. 22nd).

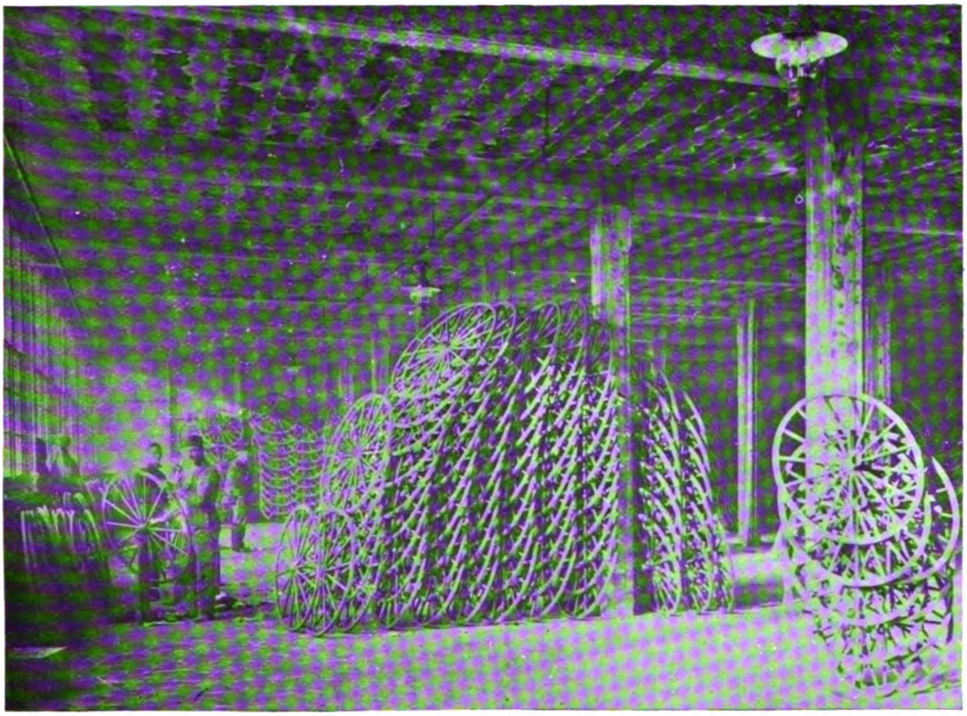
A ¾-in. by 2-in. top bar running through the column from beam to beam provides for the tensile stresses made possible by the beams acting as continuous beams, and adds an additional factor of strength as the beams are figured on the assumption of being fixed at both ends. These top bars run past the point of contra-flexure in the beams, and thereby prevent cracks from appearing in the tops of the beams near the supports due to tension on account of continuous action. The beams supporting the walls, which are 12 in. thick, and of brick, are of 9½ in. by 12 in. section in the front, and of 12-in. by 27½-in. section in the rear of the building, the front walls having a larger window area than the ones in the rear, and therefore imposing lesser loads on the beams.

The roof is constructed of 4-in. tile with 4-in. concrete joists 16 in. on centres and 1½-in. concrete slab covering the whole. The reinforcing members are one ½-in.

by 1½-in. bars for each joist and the beams supporting this construction are mainly of 10 by 18-in. cross section with two ¾-in. by 2-in. Kahn bars for each beam, and one ½ by 1½-in. top bar over each column uniting the beams and providing, similar to the floor construction, against cracks in the top near the points of support.

The interior columns supporting the roof are 12 in. sq., the wall columns mainly 12 in. by 18 in. and 12 in. by 14 in., and the columns supporting the tank framing 14 by 14 in. and 16 by 16 in. respectively. All columns are reinforced with four ½-in. by 1½-in. bars, excepting the tank-support columns, which have four ¾ by 2-in. bars as reinforcement.

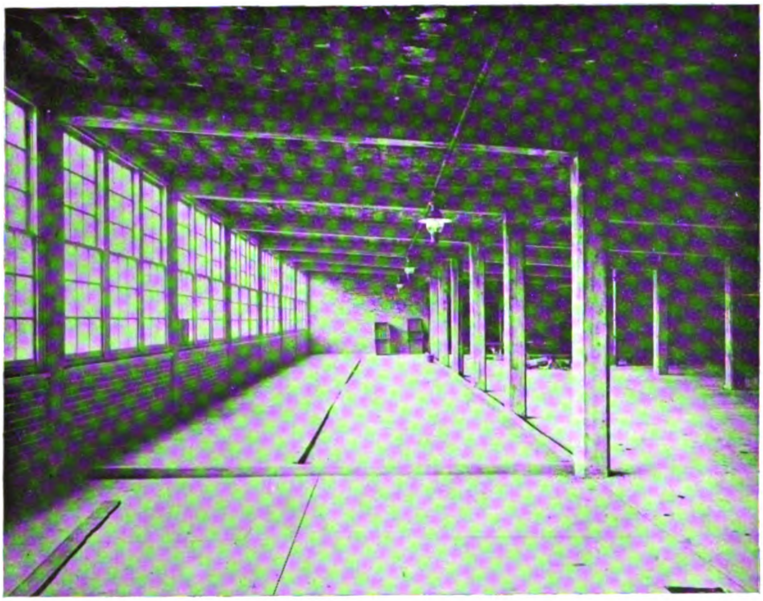
It must be noted here that the floors as well as the roof joists have ½-in. by 1½-in. top bars running over the beams, providing for continuity of the joists and considerably increasing the strength of the floor and roof system. The beams supporting the tank platform are strongly designed to carry the two 20,000 gallon tanks, the platform itself being a 5-in. solid concrete slab with ½ by 1½-in. bars spaced 16 in. on centres. The beams are spaced 5 ft. 2½ in. on centres, and are supported by 12-in. by 48-in. girders, which in turn rest directly on the columns.



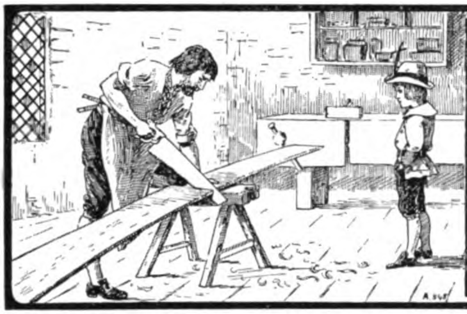
SIXTY-TWO DAYS FROM SIGNING THE CONTRACT FOR THEIR NEW BUILDING, THE ANDERSON CARRIAGE CO. WERE OCCUPYING THE SAME EIGHTEEN DAYS INSIDE OF CONTRACT TIME.

The roof slopes uniformly from the sides toward the centre of the building from where the water is drained to the ground floor and into sewers by leaders of ample capacity.

The stairways running from the ground floor up to the second and third floors are 6 in. solid concrete slab construction with solid concrete risers and treads and reinforced by $\frac{3}{4}$ by 2-in. bars spaced about 9 in. on centres and anchored into the floor construction. Over these bars are placed $\frac{1}{2}$-in. diameter cross-bars to prevent cracks due to sudden temperature changes.



An Interior View.
(No Possible Window Space Lost—No Cross Beams to Obstruct Light).



FORMS FOR CONCRETE CONSTRUCTION.

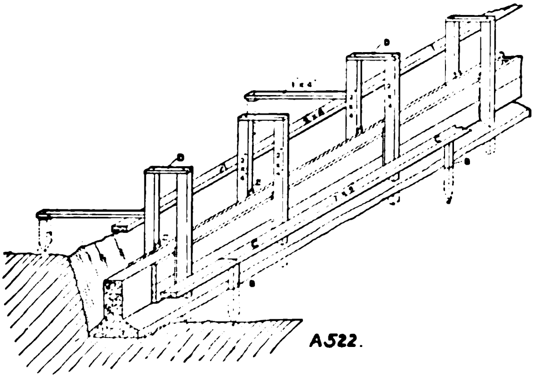
By SANFORD E. THOMPSON, M.Am.Soc.C.E.

The importance of care with the timbering necessary in the execution of reinforced concrete work can scarcely be sufficiently emphasised. Further, upon the practical arranging of the timbering and forms depends to a great extent the economical execution of any reinforced concrete structure.

Thus we are presenting, from the pen of an experienced Civil Engineer, the following article on this subject.—ED.

Recent failures in reinforced concrete construction cannot be cast one side and forgotten with the passing comment so frequently heard, that the accident was due merely to poor construction or too early removal of forms. The reasons for every failure should be thoroughly investigated by experts to prevent recurrence of similar accidents.

" Poor construction " and " forms," although frequently guilty, are by no means the only culprits. Just so long as men who know nothing of the first principles of mechanics are permitted to design concrete structures, and just so long as irresponsible contractors are engaged to erect them, the list of accidents will increase in startling numbers. It is the men—not the inanimate lumber—who are to blame in every case. However, granting its danger under ignorant hands, reinforced concrete as a whole must not be condemned for failures due to improper conditions any more than brick should be rejected as a building material for apartment houses because of the collapse of several unfinished buildings in New York city two years ago through disregard of frost action upon the mortar.



A Simple Form of Construction for a Low Foundation or Cellar Wall.

Failures in concrete buildings may be attributed to:

(1) Imperfect design; especially through neglect of essential details in locating the reinforcing metal, and through the adoption of too low a factor of safety.

(2) Poor materials; such as cement which does not properly set up, or sand which is too fine or which has an excess of clay, loam or other impurities.

(3) Faulty construction; from improper proportioning, mixing or placing, or too early removal of forms.

(4) Weak forms.

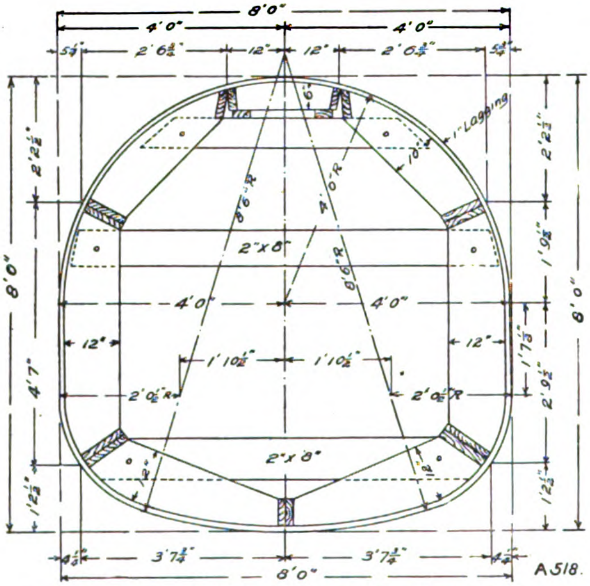
A disregard of such important principles is frequently criminal negligence, and yet in at least one case under my observation an examination of the structure and the materials after a collapse in which a number of lives were lost showed the design, materials and construction to be all so faulty that it was impossible to decide positively which of the four causes named above was the primary reason for the failure.

In this paper it is proposed to treat only of the design, construction and removal of forms.

GENERAL RULES FOR FORM CONSTRUCTION.

Kind of Lumber.—The selection of the lumber must be governed by the character of the work and the local market. White pine is best for fine facework, and quite essential for ornamental construction cast in wooden forms. For ordinary work, however, even for the panels, white pine is apt to be too expensive, and spruce, fir, Norway pine, or the softer qualities of Southern pine must be substituted for it. Some of these woods are more liable to warp than white pine, but they are generally stiffer and thus better adapted for struts and braces.

Kiln-dried lumber is not suitable for form construction because of its tendency to swell when the wet concrete touches it. Very green lumber, on the other hand, especially Southern pine, which does not close up quickly when wet, may give trouble by joints opening. Therefore, the middle ground, or, in other words, partially dry stuff, is usually best.

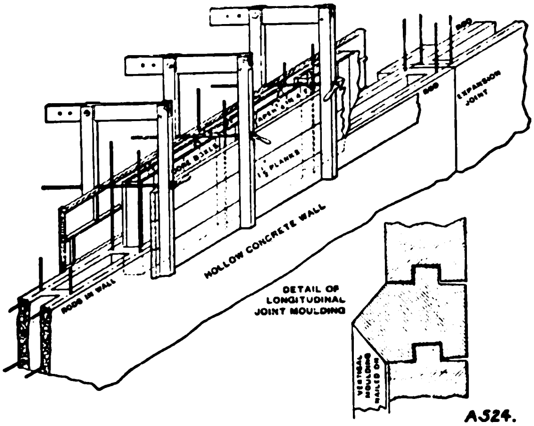


Centre for an 8-ft. Conduit used in the Pittsburg Filtration Scheme.

Finish and Thickness of Lumber.—Either tongued-and-grooved or bevel-edged stuff will give good results for floor and wall panel forms, and is preferable to square-edged stuff. A smoother surface may be attained at first with the tongued-and-grooved stock than with square or bevel-edge and there is less trouble with opening joints, but it is more expensive because of the waste in dressing, and if the forms are used many times there is a greater tendency to wear at the joints. Even for rough forms plank planed one side may be economical to cheapen the cost of cleaning. Studs should always be planed one side to bring to size.

The thickness of lumber varies with different contractors, some using 1-in., others 1½-in., while a few employ 2-in. stuff even for panels. (These are commercial thicknesses measured before planing). For ordinary walls 1½-in. stuff is good, although for heavy construction where derricks are used 2-in. is preferable, while for small panels 1-in. boards are lighter and easier to handle. For floor panels 1-in. boards are most common, although if the building is eight stories high or over, 1-in. stuff of soft wood is likely to be pretty well worn out before the top of the building is reached, and the under surface of the concrete will show the wear badly. For sides of girders either 1 in. or 1½ in. is sufficient, while 2 in. is preferable for the bottoms of girders. Column forms are generally made of 2-in. plank.

DETAILS OF FORM CONSTRUCTION.



A524.

A Style of Form Construction for Hollow Walls, using Metal Lathing which has first been plastered on the outside.

Certain general rules are applicable to all kinds of forms. Strength, simplicity and symmetry are three fundamental principles of design. The necessity for strength is obvious. Economy in concrete construction consists in quickly erecting and moving the forms and in using them over and over again.

The design of the concrete members should recognise the forms. A slight excess of concrete sometimes may be contributed to save carpenter work. Frequently beams may be designed of such widths as to use dimension widths of lumber without splitting.

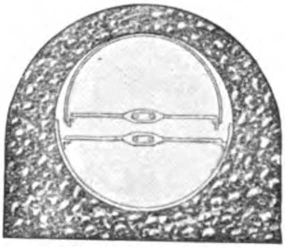
Columns may be of dimensions to avoid frequent remaking. Recesses may be made the thickness of a board or a plank. To permit ready cleaning of dirt and chips from the column forms before laying the concrete, at least one prominent contractor provides a door at the bottom of each of them.

In building construction the forms must be designed so that the column forms and also the bottom beam moulds are all independent of the slabs. The forms may thus be left a longer time upon members subjected to the greater stress.

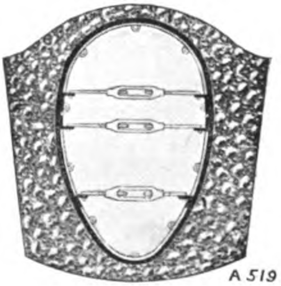
The sides of the beam forms should be held tightly together, by wedges or clamps, to prevent the pressure of the concrete springing them away from the bottom boards. Hardwood wedges at top or bottom of each strut are useful when setting and removing it, and also permit testing to make sure that there is no deflection of the beam or slab. For this purpose some contractors loosen the wedges twenty-four hours in advance of the struts. In general it is preferable to use comparatively light joists, such as 2 in. by 8 in. or 2 in. by 10 in., with frequent shores rather than to use lumber which is heavier to handle.

If forms are to be used but once, or must be taken apart when removed, it is sometimes practicable to use only a few partially driven nails so that they can be withdrawn without injury to the lumber. It is very difficult to convince house carpenters that the pressure of concrete will hold temporary panel boards in place with scarcely any nailing.

Alignment is another item of importance, since it is here that a great deal of time may be wasted by inexperienced or incompetent carpenters. Such workmen may err either on the side of poor alignment or more



"BLAW" CENTRES
Collapsed.



A519.

"BLAW" CENTRES.
In Position.

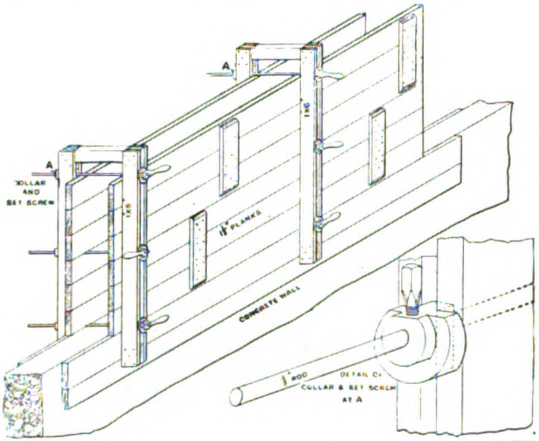
In the patented Blaw centering, the shell is of steel with turnbuckles provided to collapse the metal, as shown in the upper section of the figure.

careful alignment than the structure requires. Mr. W. J. Douglas[*] suggests as a general rule the allowance of "$\frac{3}{8}$-in. departure from established lines on finished work and 2 in. on unfinished work."

In removing forms the green concrete must not be disturbed by prying against it. This seems so obvious as to need no emphasis, but I have known first-class carpenters to actually attempt to straighten a wall which was an inch out of line the day after the concrete was laid by prying the forms over. The wall was straightened, but by a different process from that proposed by the carpenter—the concrete was relaid.

Forms for facework should be tightly put together, it being advisable in some cases to close the points and holes by mortar, putty, plaster-of-Paris, sheathing paper, or thin metal. This is not, as is commonly supposed, to prevent loss of strength bv the cement which flows out with the water, but rather to prevent the formation of voids or stone pockets in the finished surface.

Crude oil is one of the best materials to prevent adhesion of the concrete to the forms, though linseed oil, soft soap and various other greasy substances are also employed for this purpose. The oil or grease should be thin enough to flow and fill the grain of the wood.



A523

A Common Form for Building a Wall of Greater Height. As soon as a Section is Completed the Bolts are Loosened and the Slotted Form of Clamp or Brace Permits it to be Readily Moved Upward.

If the forms are to be left on until the concrete is hard, there is little danger of the concrete sticking to them if they are wet thoroughly with water before the concrete is laid instead of being greased. In any case, if concrete adheres to the forms it should be thoroughly cleaned off before resetting; even then it is apt to stick again in the same place.

DESIGN OF FORMS.

"Rule-of-thumb" layout of forms in the field is being superseded by design in the drawing-room. In building construction where the forms form a large percentage of the cost of the building, and where a failure in the forms may cause loss of life, it is especially necessary to treat this question from an engineering standpoint, and many of the best concrete contractors now design their forms as carefully as the dimensions of the concrete members.

If a minimum quantity of lumber is to be used consistent with the deformation allowed, it follows that the dimensions and spacing of the supporting lumber must be actually computed from the weight or pressure against the sheeting. For columns and for walls where a considerable height of wet concrete is to be placed at once, the pressure may be calculated as a liquid. Mr. W. J. Douglas[†] assumes that the concrete is a liquid of half its own weight, or 75 lbs. per cubic foot.

In ordinary walls, where the concrete is placed in layers, computation is not usually necessary, since general experience has shown that maximum spacing for 1-in. boards is 2 ft., for 1½-in. plank is 4 ft., and for 2-in. plank is 5 ft. Studding generally varies from 3 x 4 in. to 4 x 6 in., according to the character of the work and the distance between the horizontal braces or waling. 4 x 4 in. is the most useful size.

---

[*] *Engineering News*, Dec. 20, 1906, p. 648.
[†] *Engineering News*, Dec. 20, 1906, p. 646.

Floor forms are better based upon an allowable deflection than upon strength, in order to give sufficient stiffness to prevent partial rupture of the concrete or sagging beams.

In calculating we must add to the weight of the concrete itself—*i.e.*, to the dead load—a construction live load which may be assumed as liable to come upon the concrete while setting. Definite units of stress must also be assumed in the lumber.

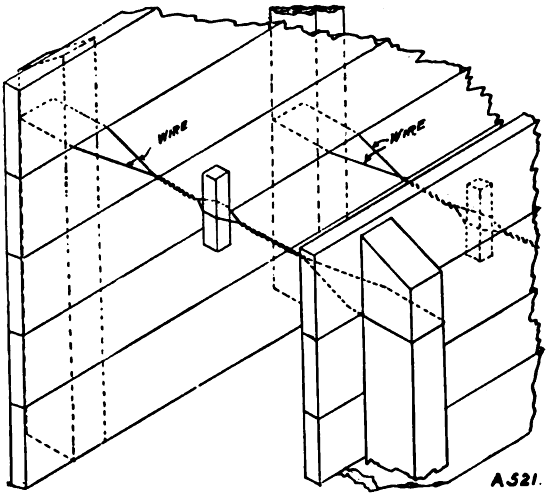
I would suggest the following basis for computation, these being values which I have adopted for use:

(1) Weight of concrete, including reinforcement, 154 lb. per cu. ft.

(2) Live load, 75 lb. per sq. ft. upon slab, or 50 lb. per sq. ft. in figuring beam and girder forms.

(3) For allowable compression in struts use 600 to 1,200 lb. per sq. in., varying with the ratio of the size of the strut to its length. (See table below.) If timber beams are calculated for strength, use 750 lb. per sq. in. extreme transverse fibre stress.

(4) Compute plank joists and timber beams by the following formula, allowing a maximum deflection of ⅛ in.:



Form for using in the Construction of a Heavy Wall, where the Ties consist of wire twisted to hold the Side Forms in place.

(1) (2)

$$d = \frac{3}{384}\,\frac{Wl}{EI} \quad \text{and} \quad I = \frac{bh^3}{12}$$

in which d = greatest deflection in inches;
W = total load on plank or timber;
l = distance between supports in inches;
E = modulus of elasticity of lumber used;
I = moment of inertia of cross-section of plank or joist;
b = breadth of lumber;
h = depth of lumber.

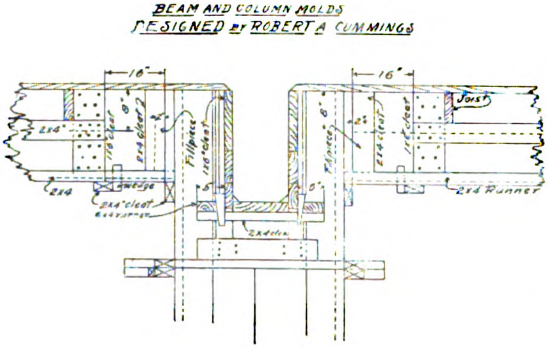
The formula is the ordinary formula for calculating deflection except that the coefficient is taken as an approximate mean between 1/384 for a beam with fixed ends and 5/384 for a beam with ends simply supported.

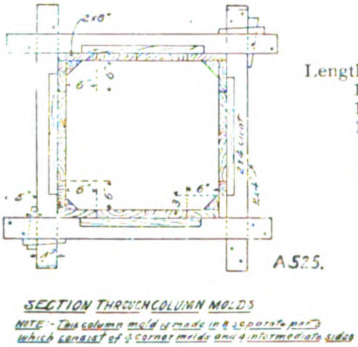
For spruce lumber and other woods commonly used in form construction, E may be assumed as 1,300,000 lb. per sq. in.

Formula (1) may be solved for I, from which the size of joist required may be readily estimated.

The weight of concrete per cubic ft. is somewhat higher than is frequently used, but is none too much where a dense mixture and an ordinary percentage of steel is used. For very rough calculation, however, it is frequently convenient to remember that 144 lb. per cubic ft. is equivalent to the product of the dimensions of the beam in inches times a length of one foot.

The suggested live load is assumed to include the weight of man and barrows filled with concrete, and structural material which may be piled upon the floor, not including, however, the weight of piles of cement or sand or stone, which should never be allowed upon a floor unless it is supported by concrete sufficiently strong to bear the weight, or by struts under all the floors below.




2x8"
6"
6"
6"
6"
5"
6"
3"
2x4 cleat
2x4
1"
A525.
SECTION THROUGH COLUMN MOLDS
NOTE:- This column mold is made in 8 separate parts which consist of 4 corner molds and 4 intermediate sides

This is an Ordinary Type with Special Features In order to hold the Sides of the Beam Forms against the Bottom Board, a 2 by 4 in. Runner with Wedges against it is used.

The units for stress in struts are somewhat higher than in timber construction because the load is a temporary one. The extreme variation given is due to the fact that when a column or strut is longer than about sixteen times its smallest width there is a tendency to bend, which must be prevented, either by bracing it both ways or allowing a smaller load per square inch. For struts ordinarily used the following stresses may be assumed for different heights:

Safe Strength of Wood Struts in Forms for Floor Construction.

Pounds per Sq. In. of Cross-Section.

Length of Strut	3" x 4"	4" x 4"	6" x 6"	8" x 8"
14 ft.		700	900	1100
12 ft.	600	800	1000	1200
10 ft.	700	900	1100	1200
8 ft.	850	1050	1200	1200
6 ft.	1000	1200	1200	1200

Bracing both ways will, of course, reduce the length of a long strut.

If the concrete floor is comparatively green, the load must be distributed by blocking, preferably of hard wood. At the top of the strut provision must be made against crushing of the wood of the plank or cross-piece. Ordinary soft wood will stand without crushing only about 700 lb. per sq. in. across the grain, so if the compression approaches this figure brackets must be inserted or hard-wood cleats used.

TIME TO MOVE AFTER PLACING.

The best contractors have definite rules for the minimum time which the forms must be left in ordinary weather, and then these times are lengthened for changes in conditions according to the judgment of the foreman.

Conference with a number of prominent contractors in various parts of the country indicates substantial agreement in the minimum time to leave forms. As a guide to practice the following rules are suggested, these following in the main the requirements of the Aberthaw Construction Company:

Walls in mass work: one to three days, or until the concrete will bear pressure of the thumb without indentation.

Thin walls: in summer, two days; in cold weather, five days.

Slabs up to 6 ft. span: in summer, six days; in cold weather, two weeks.

Beams and girders and long span slabs: in summer, ten days or two weeks; in cold weather, three weeks to one month. If shores are left without disturbing them the time of removal of the sheeting in summer may be reduced to one week.

Column forms: in summer, two days; in cold weather, four days, provided girders are shored to prevent appreciable weight reaching columns.

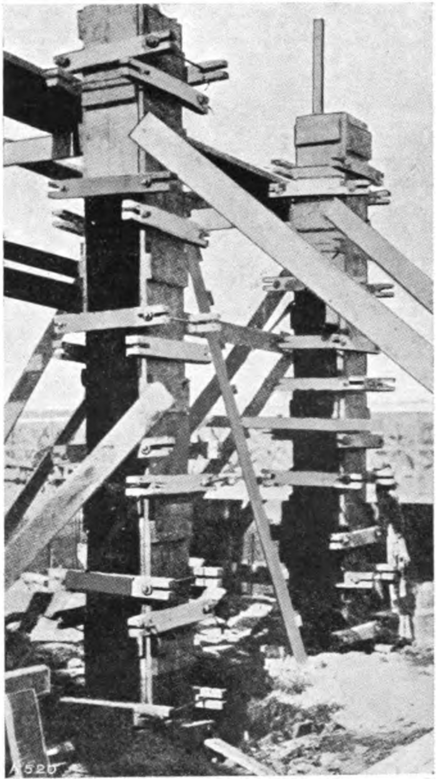
Conduits: two or three days, provided there is not a heavy fill upon them.

Arches: of small size, one week; for large arches with heavy dead load, one month.

All of these times are, of course, simply approximate, the exact time varying with the temperature and moisture of the air and the character of the construction. Even in summer, during a damp, cloudy period, wall forms sometimes cannot be removed inside of five days, with other members in proportion. Occasionally, too, batches of concrete will set abnormally slow, either because of slow setting cements or impurities in the sand, and the foreman and inspector must watch very carefully to see that the forms are not removed too soon. Trial with a pick may assist in reaching a decision.

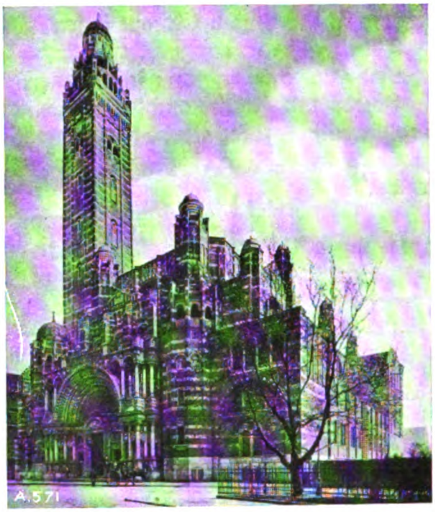
Beams and arches of long span must be supported for a longer time than short spans, because the dead load is proportionately large and therefore the compression in the concrete is large even before the live load comes upon it.

The general uncertainty and the personal element which enters into this item emphasise the necessity for some more definite plan for insuring safety. The suggestion has been made that two or three times a day a sample of concrete be taken from the mixer and allowed to set on the ground under the same conditions as the construction until the day when the forms should be moved. These sample specimens may be then put in a testing machine to determine whether the actual strength of the concrete is sufficient to carry the head and construction loads. Even this plan does not provide for the possibility of an occasional poor batch of concrete, so that watchfulness and good judgment must also be exercised.



A Common Style of Forms, as used in the erection of the Harvard Stadium.

The Concrete Domes at the Westminster Cathedral.



At a time when so much is being written about reinforced concrete, it is well to remember that important structures are continually being carried out in what may be termed "plain" concrete, i.e., concrete that is not in any way reinforced by metal.

We present, as an instance of recent concrete work of a highly skilled nature, particulars of the Domes of the Westminster Cathedral, which is built from the designs of the late Mr. J. F. Bentley.

We are indebted to Mr. John A. Marshall for the loan of the detail drawings, and also for the particulars presented.—ED.

THE following are particulars in note form of the concrete work in the Nave Domes, the Sanctuary Dome, and the Galleries, etc., at the Westminster Cathedral. Attention is specially called to the date presented as to the nature of the concrete used.

Nave Domes.—The circle, developed by the pendentives, is 60 ft. in diameter; the base of the dome is corbelled over from this, so that the springing is clearly defined, and a salient angle at the junction of the two surfaces is thus avoided, for the convenience of the mosaic workers of a future generation.

The thickness of the domes at the springing is 3 ft., which is gradually reduced to 13 in. at the crown; the curve of equilibrium is therefore well within the material.

The domes were turned on closely boarded centering, in a series of superimposed rings of concrete averaging 4 ft. in width. The concrete was not reinforced in any way. The centering consisted of radiating trusses supported from the ground, on uprights 90 ft. in height, made of stout planking, bolted together, so as to break joint, and cross-braced at intervals. It was, of course, important to have the centering perfectly rigid to preserve the true curvature of the concrete until it had finally set. Full responsibility for the centering rested with the builder who had contracted to carry out the work; and if his method lacked the daring and skill of a Brunelleschi or a Fontana, he certainly incurred no risk, and did not stint the timbering. The eastern dome of the nave was turned first, then the dome of the sanctuary, next the middle dome of the nave, and lastly the western dome. Their construction occupied about 14 months.

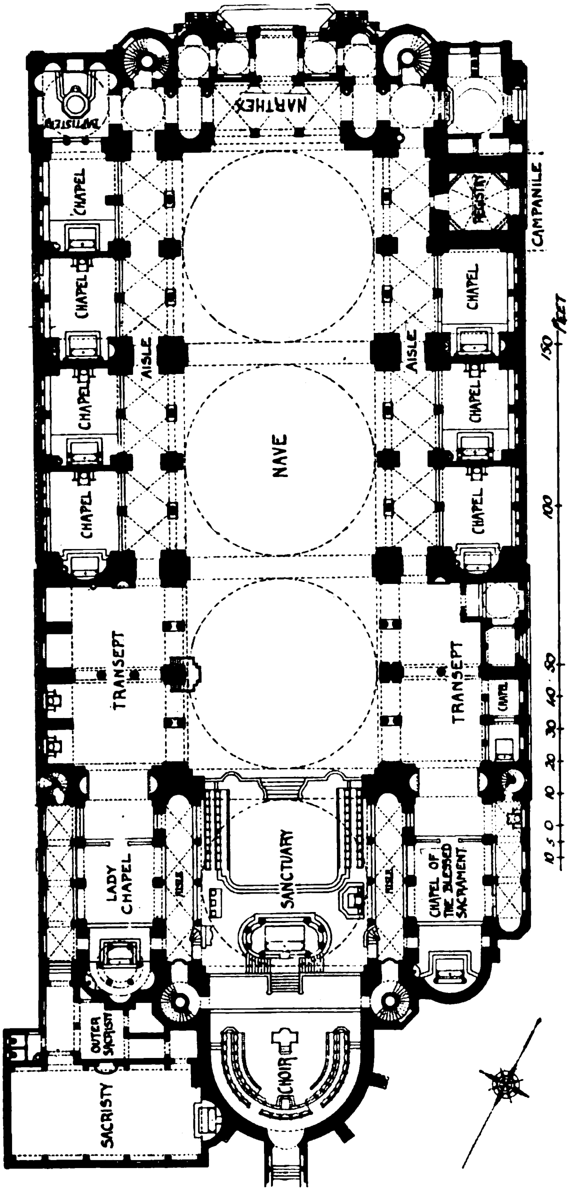
The independent external covering of the domes is formed of 3 in. artificial stone slabs, cast to the curve. They rest on radiating ribs of 5 in. deep, of similar material, fixed on the concrete, and rebated to receive the slabs, thus leaving an air-space of

2 in. between the inner shell and the outer covering, the object being to render the temperature of the interior more uniform. The top and bottom joints of the slabs are rebated. At the springing and at the crown the spaces between the ribs are left open for ventilation, and to prevent the wet being driven into the cavities at the top a circular-raised curb is formed on the top edge of the upper slabs, over which is placed a domical capping that allows the air to circulate freely. To form the outer covering more than 600 slabs were required for each dome; the exposed surface is, therefore, an elaborate network of jointing, and we cannot but feel that an outer coating of a homogeneous material would have been more impervious.

The concrete flat roofing around the domes is covered with asphalte that passes up the lower portion of the dome to a height of about 4 ft. 6 in. under the outer covering, where it is keyed into the concrete.

The Sanctuary Dome.—As to the eastern dome, it differs in several respects from those of the nave. Unlike the latter, that seem to rest on the flat roofing of the church, the dome of the sanctuary emerges gradually out of the substructure, the extrados of the pendentives forming a pyramidal series of offsets or steps, that follow the plan of the dome.

The abutment for the main supporting arches of the sanctuary dome is provided by the staircase turrets on the east, and by the transept piers on the west; while for the dome itself abutment is provided on the north and south by the vaults over the organ galleries, on the west by the dome of the nave, and on the east by buttresses built on the wide supporting arch that forms part of the vaulting to



PLAN—WESTMINSTER CATHEDRAL.

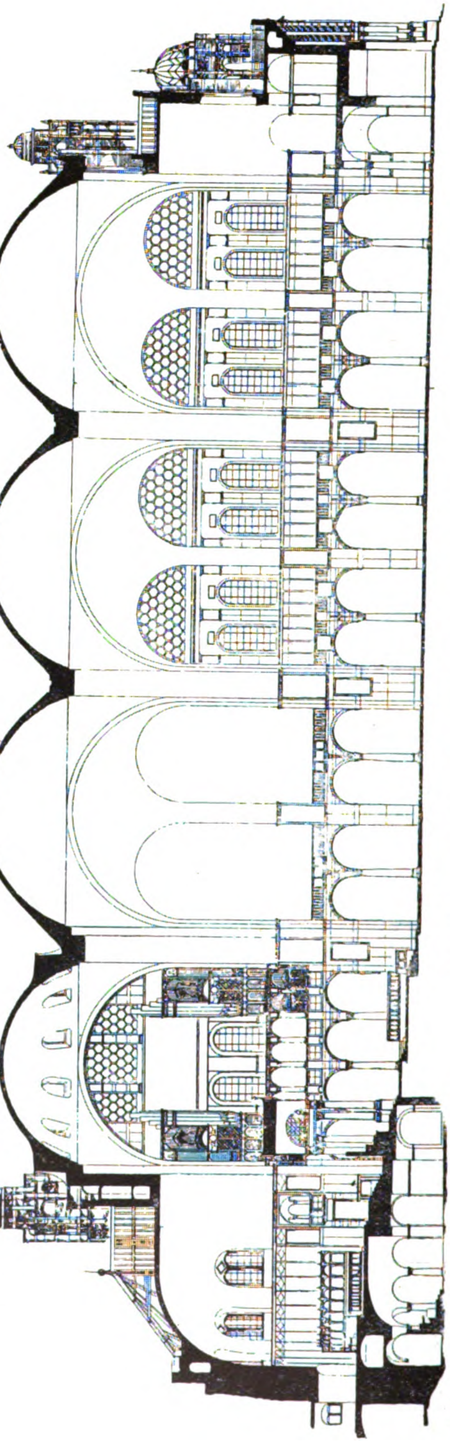
By courtesy of the "Builders' Journal."

the choir; these buttresses are stiffened by the outer wall of a passage way that passes through them, to provide communication between the staircase turrets.

The circle developed by the pendentives is 52 ft. in diameter. On the closely-boarded centering for this dome other centering had to be constructed for the window openings, the reveals of which represent a series of counterforts all round the dome. Centering had also to be constructed for the wall of the drum, or circular podium, designed to disguise the counterforts, and to protect the glazing from the drainage of the dome.

The cavities between this wall and the shell of the dome are covered by slabs of concrete, weathered to a sunk gutter or channel near the outer edge, that conveys the water to projecting spouts, or gargoyles, placed between the windows. The flat of the drum is covered with asphalte that passes partly up the dome under the outer covering, as before described. The exposed vaulting and the pendentives around the dome are also asphalted; the wall of the podium is cemented.

The Galleries.—The organ galleries are independent factors of the construction, and, like the galleries of the nave, were left down until the main parts were built. The concrete vaulting of these galleries and the western gallery of the nave is not let into the walls at the back, but supported on brick and stone corbelling, so that the walls are not weakened; the concrete was, however, keyed to the wall by projecting courses of brick, and, as an extra precaution, the columns supporting the vaulting of the organ galleries are tied to the brick wall by gun-metal ties, while for the west gallery of the nave ties were inserted at the floor level of the gallery, where the wall of the narthex has most resistance.

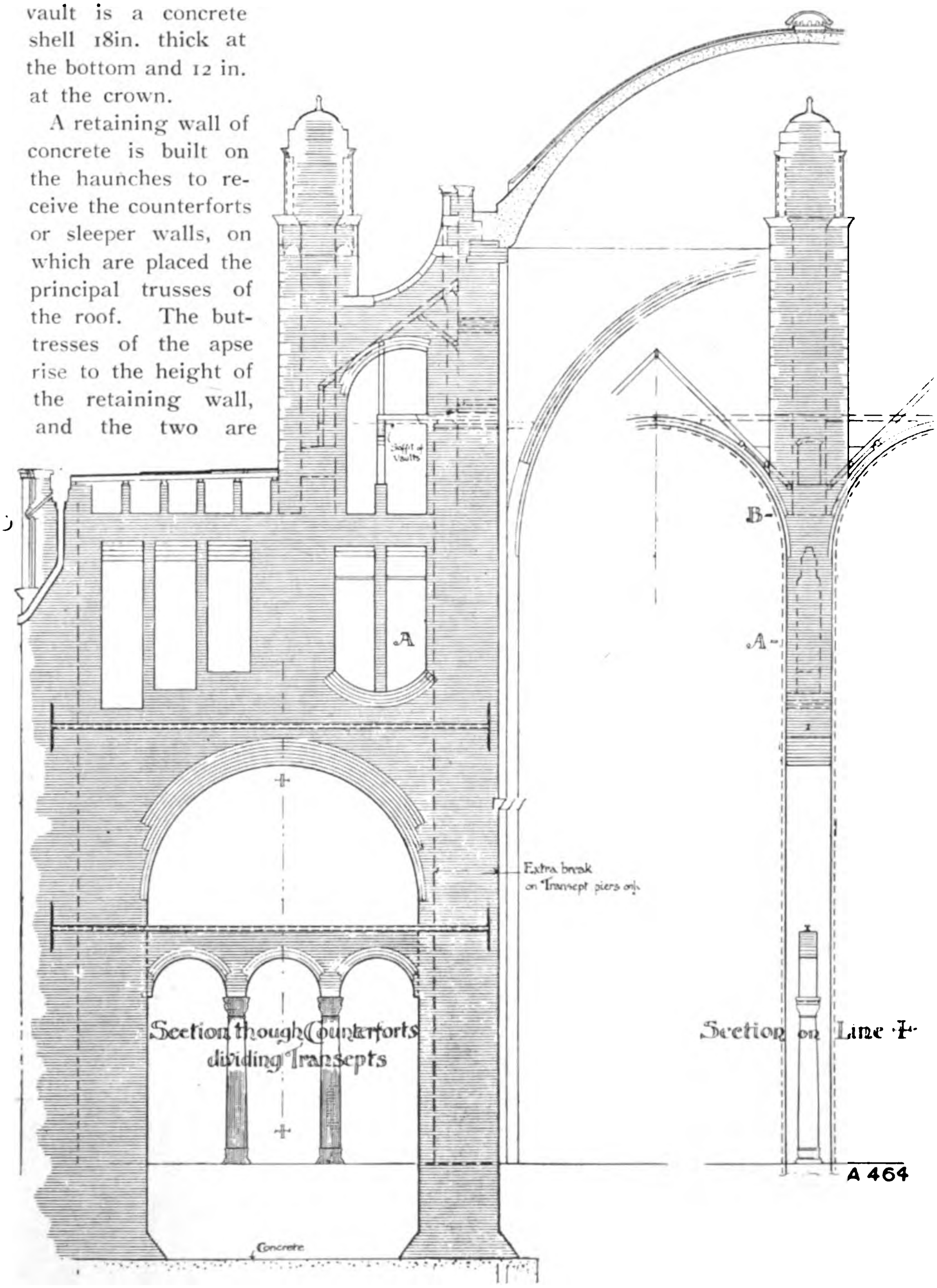


SECTIONAL PLAN—WESTMINSTER CATHEDRAL.

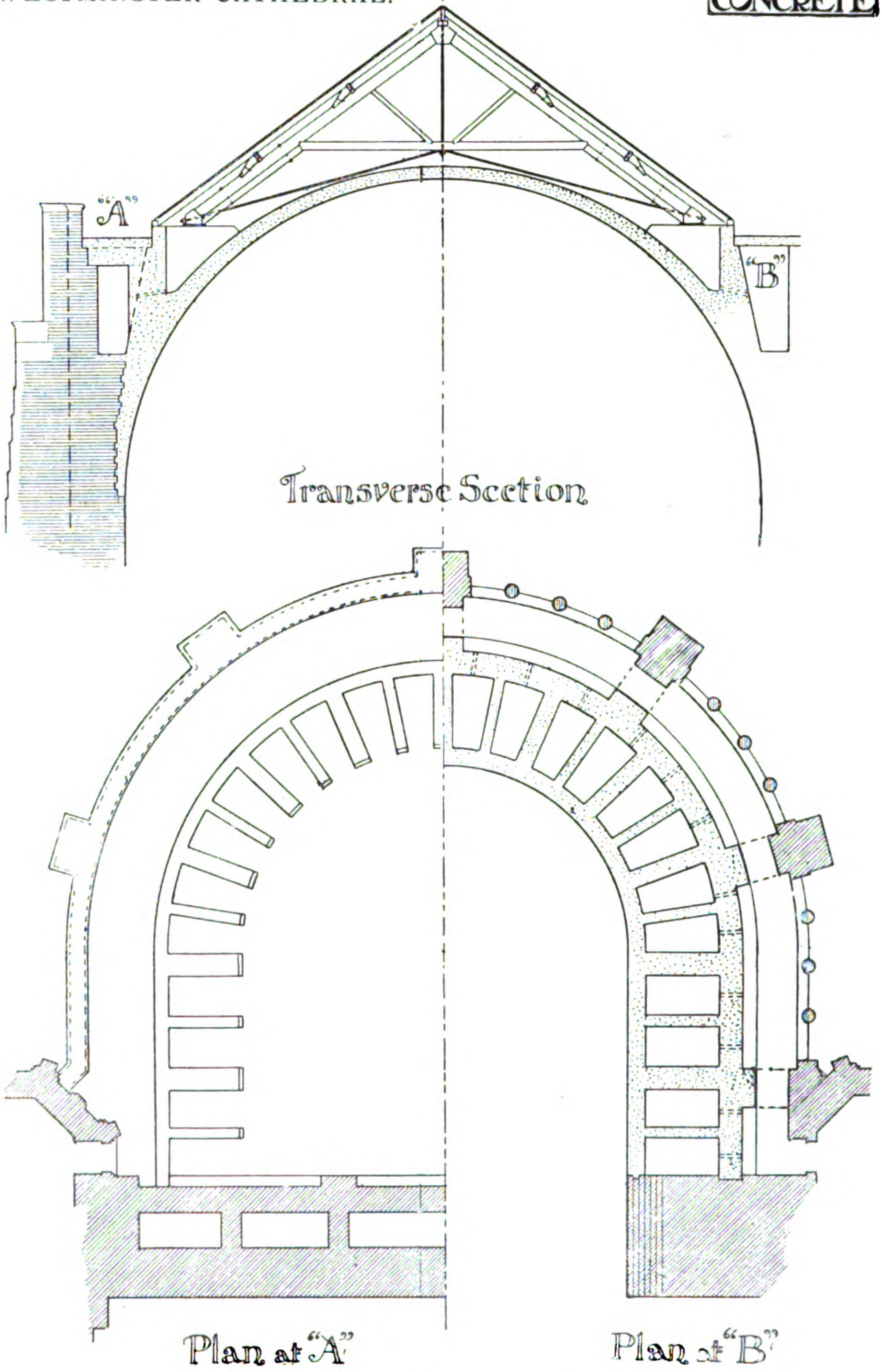
By courtesy of the "Builders' Journal."

The Choir.—Up to nearly half its height the vault is a solid mass of brickwork roughly corbelled over to the curve and faced with concrete. Above this level the vault is a concrete shell 18in. thick at the bottom and 12 in. at the crown.

A retaining wall of concrete is built on the haunches to receive the counterforts or sleeper walls, on which are placed the principal trusses of the roof. The buttresses of the apse rise to the height of the retaining wall, and the two are

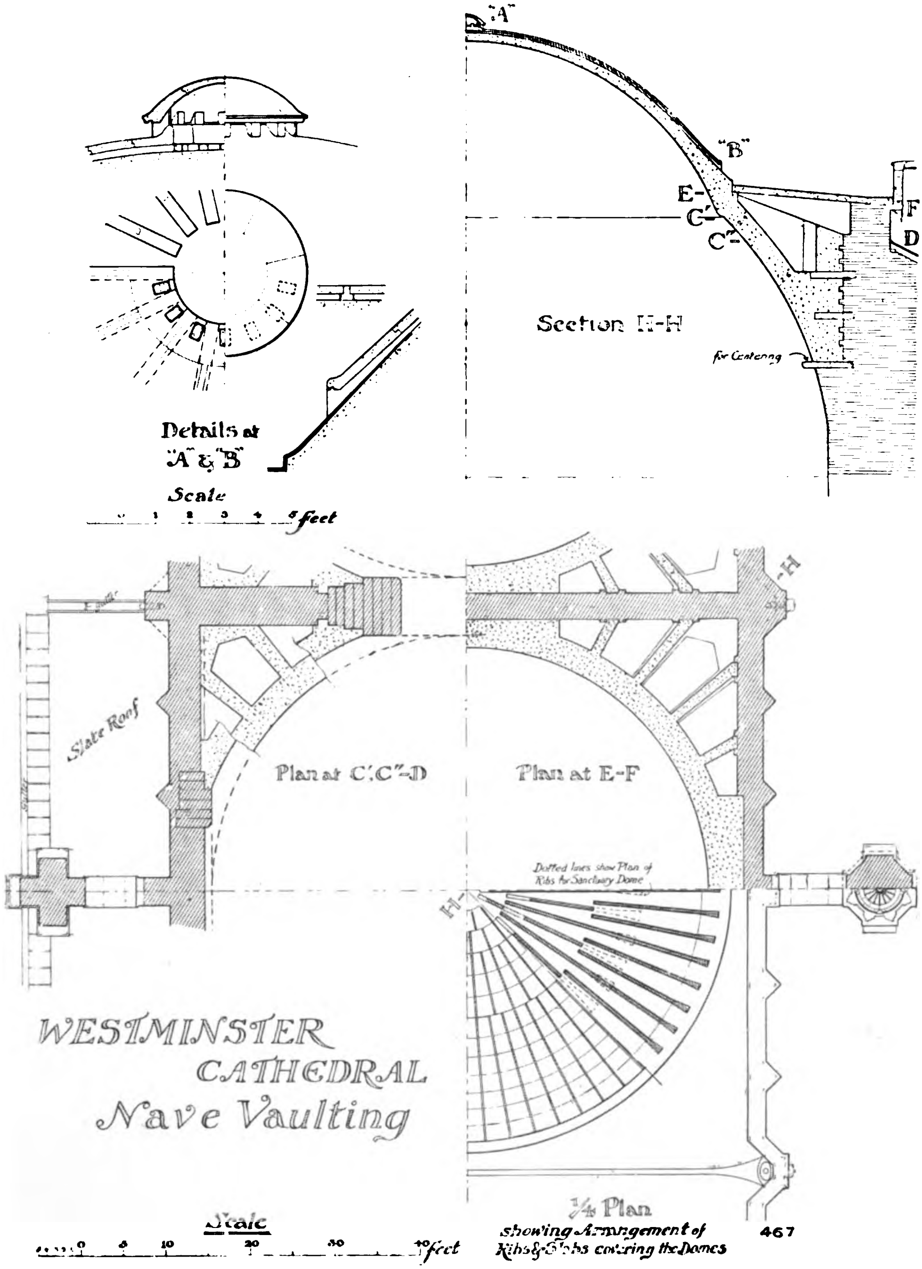

Soffit of Vaults
A
B-
A-
Extra break on Transept piers only
Section through Counterforts dividing Transepts
Section on Line I
Concrete
A 464

SECONDARY COUNTERFORTS DIVIDING TRANSEPTS.

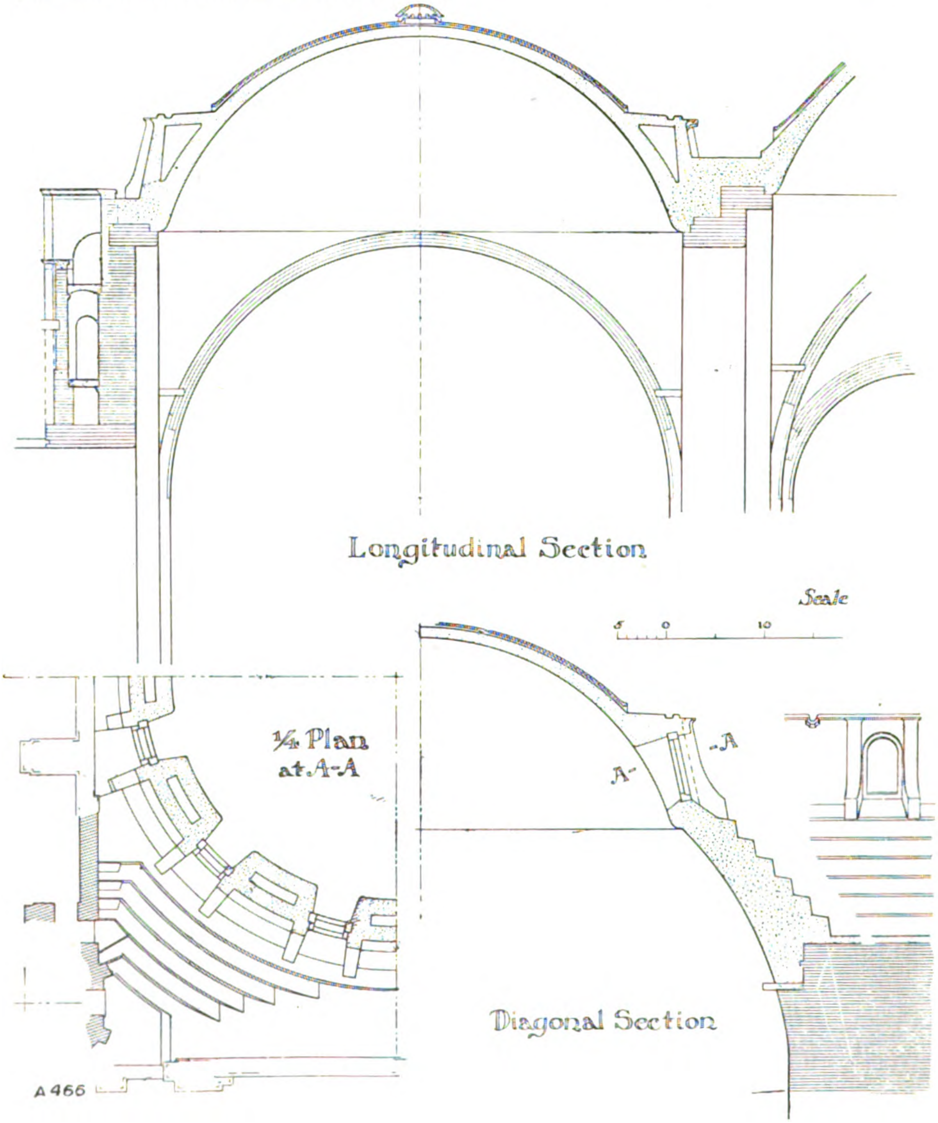


Vaulting of Choir, Westminster Cathedral.

connected by massive concrete lintols, formed across the gallery behind the buttresses. The gallery is covered with concrete slabs cast *in situ*, that form a flat around the timber roof. To prevent the arcades of the gallery being pushed out by the expansion of the concrete the flat and the lintols were kept clear of the brickwork, until the concrete had thoroughly set. The joints were then made good.



The Concrete Used.—The concrete for the domes consisted of four parts (by measurement) of clean, hard brick refuse from the brickyards, broken to a walnut gauge and well saturated with water before mixing and one part of Portland cement. The mixing was done on a stage around the domes, and the concrete was thrown on the cleanly boarded centering that was sanded to prevent the adhesion of the concrete to the boarding. The upper surface of the domes was screeded to a graduated thickness. During the hot weather the domes were sprinkled with water to prevent the cement setting too quickly. The Portland cement on delivery was poured out of the bags on to the floor of a shed and turned over occasionally, so that the air could pass over it to cool it before it was used.



Details of Sanctuary Dome, Westminster Cathedral.

Standard Fire-Resisting Construction in Relation to the Present Rules of the Fire Offices Committee.

By F. A. MACDONALD (Glasgow).

We are publishing, almost complete, a most interesting paper presented to the Insurance Institute of Edinburgh by Mr. F. A. Macdonald, District Engineer to the Hennebique System in Glasgow.

This is, we believe, the first instance in which a representative of the reinforced concrete trade has put forward well-reasoned technical arguments, as distinct from salesmen's statements, and it is pleasant to observe that in matters of principle the author's views seem to accord with ours.

Space has precluded our publishing the examples presented by the author, but we should mention that these examples are perhaps not quite so free from controversy as we could desire, where the author's case for fire resistance is so good.

The author's suggestions as to fire tests with concrete work of suitable seasoning, ana those as to the modification of the Fire Office Rules as to thickness of dividing walls, should command the immediate attention of the British Fire Prevention Committee and the Fire Office Committee respectively.

As to his arguments regarding artificial concrete aggregates, we think it will be well to await the finding of the special Commission on Concrete Aggregates before taking up the subject, but on this point our views are not at one with the author's.—ED.

THIS title opens up a very wide field, but I do not propose to attempt to treat such a subject exhaustively, but rather to confine myself to certain points to which I wish specially to draw your attention.

It has been very aptly stated that resistance to fire—and, in fact, resistance to aggression of any kind—may either be of the nature of a passive resistance or of the nature of an active resistance.

In case of fire the term "active resistance" may be defined to mean sprinklers, and private and public fire extinction appliances. The term "passive resistance" may be defined to mean a form of building construction which is not only in itself incombustible, but which also is least affected by heat or violent fluctuations of temperature, and, further, which is combined in design with a knowledge of the fire hazard, resulting from the occupancy of the building and from its exposure to surrounding hazards.

The most important of these two forms of resistance is undoubtedly the latter, because if in the design of a building a fire-resisting form of construction is adopted, and the risk of fire resulting from the occupancy and from exposure is foreseen and met beforehand to the greatest extent possible, then the danger of a fire making headway is reduced to the minimum, and the task of extinction rendered comparatively easy. The extinction of fire therefore takes a secondary place, or should take a secondary place to fire-resisting construction and design made with a view (1) to lessen the hazard of an outbreak of fire, and (2) to limit the area of a fire when once it has broken out.

The importance of this is in proportion to the severity of the risk resulting from the occupancy or from the exposure hazard—that is to say, the greater the fire risk the more need is there for fire-resisting construction and for appreciation of the hazard so that this may be met in the constructional design.

In saying this I do not wish to undervalue the function and importance of public and private fire extinction appliances. These appliances are always necessary, but they are devoted to the extinction of fire, and fire-resisting construction and design are devoted to the prevention and limitation of fire. . . .

In giving consideration to a form of construction and design which shall be as far as possible "fire-resisting," there are factors other than the actual combustibility of the structural materials to which attention should be given. Such factors are—(1) diminution of strength of certain materials at increased temperatures, (2) efforts of expansion and contraction, and (3) resistance to disintegration under the application of heat and water.

These factors and others have been recognised by the Fire Offices Committee, which body has drawn up a set of rules bearing on the subject. These rules, I take it, are meant to serve as a guide not only to the insurance manager and surveyor, but also to the person to whom the design and execution of the fire-resisting structures may be entrusted.

These rules lay down certain regulations as to height, cubical capacity, thickness of walls, superficial area of openings in walls, position of windows, construction of floors and roofs, protection of structural metal work, floor openings and communicating compartments.

Generally speaking, I think that all buildings may be separated into four classes, as follows:—

1. Combustible buildings which are of ordinary stone or brick construction with wood floors and wood and slate roofs, and which make no pretension of being fireproof.
2. "Slow burning" buildings having floors and beams of very heavy wood construction. This class may be passed over with bare mention, as such buildings are not to be commended on account of the very heavy smoke damage which always results, and also because they are rarely met with and are likely to remain so on account of the rapidly increasing cost of timber.
3. Buildings constructed with combustible materials but in which the structural metal work is partly exposed. Such buildings are frequently met with. They are in no sense "fire-resisting," and form a class in reality more dangerous than either Nos. 1 or 2.
4. Fire-resisting buildings constructed in accordance with the rules of the Fire Offices' Committee.

It is therefore only Class 4 with which I have to deal, a class in which practically all combustible structural materials are prohibited and only incombustible structural materials allowed to be used, all such materials as are largely influenced by heat being protected and insulated.

DATA AS TO STEEL.

As is well known, steel and iron are materials which are practically indispensable for the construction of a modern warehouse or factory, designed to be fireproof. Internal iron or steel columns or stanchions are almost invariably used to support the floor areas, and the floors themselves—whether fireproof or not—are carried between the columns by steel joists or girders. The influence of temperature on iron or steel is very marked. At high temperatures these materials tend to become plastic and then molten. In other words, they lose their power of resistance to loads, and if not in some way protected or insulated from the influence of heat their ultimate collapse at high temperatures is certain.

Some actual data as to the influence of temperature on these materials may be of interest.

The following table was compiled by Kollman, the resistance at O°C. (32° F.) being taken as equal to 100:—

Temperature Fahrenheit.	Wrought Iron	Steel (Bessemer).
32	100	100
212	100	100
392	95	100
572	90	94
932	38 Plastic	34
1203	16	18
1652	6	9
1832	4	7

The melting points given by Le Chatelier are: For cast-iron 2228° Fahr.; for soft steel 2685° Fahr.; for hard steel 2570° Fahr. The highest temperature attained in a blast furnace is 3506° Fahr.

In the process of manufacture of steel the temperature attained when the steel is in a molten state is 3000° Fahr. in the Bessemer process, and 2882° Fahr. in the Siemens-Martin process.

With these figures before us, and keeping in view that the temperature in the heart of a building on fire may attain to 2000° Fahr., the absolute necessity of fully and adequately protecting all structural iron and steelwork will be readily admitted.

GENERAL FIRE OFFICE RULES.

The rules of the Fire Offices Committee provided for this by stating that all structural metal work shall be encased with brick work, or with porous terra-cotta, or with cement, concrete or plaster, in thickness varying from one to two inches.

Probably no better material can be found for resistance to fire than good, well-burnt brick, but to encase a column in solid brickwork has the disadvantage that the resulting pier takes up a great deal of valuable internal space. The proper protection of joists or girders with bricks is for obvious reasons cumbersome and difficult, and for the protection of these members porous terra-cotta or hollow tiles are sometimes used.

I would, however, deprecate the use of porous terra-cotta or slabs of concrete moulded beforehand, by means of which the soffits of the beams are protected. These slabs are generally attached to the under flange of the beam by means of a terra-cotta slab being notched into the flange, or in case of concrete slabs moulded beforehand by having a strip of metal embedded in the concrete, which is turned over the lower flange. Such form of protecton is not monolithic and solid with the main metallic member, and when subject to violent heat and the subsequent application of a strong jet of water from a fire-hose pipe, these slabs are liable to fall off, leaving exposed the soffit surface of the joist or girder.

At the conflagrations at Baltimore and San Francisco, I understand that this took place to a considerable extent in buildings where such a form of construction was used. . . .

The rules of the Fire Offices Committee state that the porous terra-cotta must be "securely anchored" to the metal work, but no definition of this term is given, thus leaving the design of the anchorage to each individual designer, with no doubt widely varying results. The other method of insulation permitted by the rules—namely, protection with cement concrete or cement plaster—is probably the most practical method and the one most commonly used.

When placing in close contact with each other two substances for the purpose of protecting one of these substances by means of the insulation afforded by the other against violent fluctuations of temperature, it is important that the two substances should have relatively the same co-efficient of expansion and contraction under varying temperatures. Concrete and steel are two substances which, although widely dissimilar in character, have curiously enough almost the same co-efficient of expansion and contraction under varying temperatures. To be exact, this co-efficient is identical for these two substances up to the fifth decimal place. For this reason it is possible to place these two substances in close contact with each other without the danger of stresses being set up by unequal expansion and contraction, and causing dissociation. There can be no doubt that this is an exceedingly important consideration, and points to concrete as being a highly suitable material for insulating or protecting steel from fluctuations of temperature. Further, concrete has a large calorific capacity, or in other words it is a good non-conductor of heat.

AGGREGATES.

In utilising concrete as a fire-resisting material, attention should be given to the aggregate employed in making the concrete. Certain aggregates seem to resist the action of fire better than others, but this should not be the only standpoint from which this important question is viewed, because many aggregates (which offer a good resistance to the action of fire) may be deleterious to the permanency and durability of structural steelwork when placed in permanent contact with it.

The aggregates for concrete given in the order of their resistance to the action of fire seem to be as follows:—

(1) Coke Breeze.
(2) Burnt Ballast.
(3) Furnace Slag.
(4) Broken Brick.
(5) Furnace Clinker.
(6) Ballast.
(7) Broken Granite.

The tests of the British Fire Prevention Committee seem to point to the use of burnt ballast, furnace slag or furnace clinker as being the best aggregates for resistance to fire. This may be the case, but the use of these aggregates presents this very serious drawback, that such materials may contain in their chemical composition a proportion of sulphur, and the presence of sulphur is unfortunately apt to set up corrosion of the imbedded steel work. In view of this it is, I think, unfortunate that the Fire Offices Committee should recognise the use of such aggregates because in an indirect way this tends to encourage the use of what may be a very dangerous material from a constructional point of view. Such material, being cheaper than natural gravel or pure broken stone, will, in view of such recognition, be used unhesitatingly by many people without any consideration as to the chemical composition of the aggregate and its ultimate effect on steel.*

---

* The Special Commission on Concrete Aggregates is sitting at the present time and investigating these questions. An interim report specifying the exact nature of the aggregates is expected this year. There has been a considerable misuse of trade terms and misunderstanding on this question which may occasionally have led to accidents.—Ed.

In this connection I read recently that in a report of a special committee of the Structural Association of San Francisco cases of corrosion of steelwork where concrete made with such aggregates had been placed in permanent contact with it, and had actually been found. The age of the floors which were broken up, and in which this was found, varied from four to ten years. In the report alluded to it was stated that sulphur, as sulphur, will probably not attack iron or steel, but when oxidised and in the form of H_2SO_4 there is little doubt as to its destructive properties. It would seem that such corrosion may be set up by any concrete with aggregates of cinders, coke breeze, destructor refuse, clinkers or slag. No weakening of the embedded steel may be developed for years, but the latent possible danger with such aggregates is surely a very serious matter, and one which demands the close attention of the constructional engineer.

A material which one often hears recommended as an aggregate for concrete used in the construction of fireproof floors is coke breeze. This material is favoured by the contractor on account, principally, of its cheapness in cost, its comparative lightness and its so-called fireproof qualities. What is really meant by the term "Coke Breeze"* is no doubt the clinker of coke, but what is used as "Coke Breeze" is generally the smaller lumps riddled out of coke. It seems to me that it would be quite as efficient, so far as fireproof qualities are concerned, to use small coal as the aggregate for the concrete, and in both cases the result would be equally fireproof. I need hardly add that failure in such an instance under the test of an actual fire is probable, and in several cases has actually occurred.

It will then be asked which aggregates are the safest to use for concrete in buildings designed to be fireproof. After having given the subject the most careful attention, I have come to the conclusion that, viewing the matter not solely from the standpoint of fire-resisting qualities, but also from a standpoint which is, after all, of the first and most essential importance—namely, the permanence and durability of the structure itself—the materials which may most safely be used are the pure, natural materials: for example, broken whinstone, which is of a volcanic nature, or gravel. Concrete made with natural aggregates may have slightly less resistance to the action of fire than concrete made with certain artificial aggregates, such as coke breeze, clinker, destructor refuse, or slag, but the difference is one of degree only and is not important. Moreover, this difference is more than counterbalanced by other advantages in favour of the natural aggregates, as concretes made with certain artificial aggregates are not so reliable in their uniformity in resistance to crushing or tension, and therefore under stresses from whatever cause resulting I would be inclined to place greater reliance on the more uniform and stronger material. In addition to this, as I have already stated, there may always be the possibility of the presence of sulphur in such artificial aggregates which by chemical action may ultimately affect the structural steelwork, and consequently the permanency and safety of the building. On the other hand, it is universally recognised that concrete made with pure natural aggregates, and of sufficient density, will absolutely protect steelwork embedded in it from corrosion or oxidisation.

REINFORCED CONCRETE.

. . . The meaning of the term "Ferro-Concrete or Reinforced Concrete Construction" is defined by the rules to be "Buildings constructed with concrete reinforced in every part with embedded metal rods or bars spaced not more than 12 in. apart, securely connected or overlapping at least 6 in. at all abutments and intersections, having also bands or bars across the thickness of the concrete."

This definition is simple and clear, and as this form of construction probably attains more closely to a realisation of "fire-resisting" construction than any other, and as therefore it is of considerable importance and may be unknown to many of you, a general description may be of some interest. *(Description of Reinforced Concrete follows here).* . . . .

I have stated that such a building approximates more closely than any other fireproof construction, and my reasons for this statement are:—

(1) The non-concentration or diffusion of the structural metal work throughout the mass.

(2) The thorough encasement of the relatively small metal sections by the concrete.

---

[*] The Special Commission on Concrete Aggregates is sitting at the present time and defining, among other matters, the exact character of "coke-breeze."—Ed.

(3) The solid and monolithic character of the resulting structure, and the absence of joints.
(4) The absence of concealed spaces.
(5) The complete absence of combustible structural material.

I saw reported in a technical journal recently a paper devoted to this form of construction, which was read by Mr. James Sheppard, chief surveyor of the North British and Mercantile Insurance Company, London, before the International Fire Congress at Milan, and in which many exceedingly valuable and interesting remarks are made, to one or two of which I would refer.

MR. JAMES SHEPPARD'S VIEWS.

Mr. Sheppard stated that "Experts in reinforced concrete buildings agree that to obtain the best results (considered only from a structural point of view and under normal conditions) reinforcing rods must be placed near the outer surface of the concrete, a thickness of one inch in front of the rods being generally adopted, but this thickness is altogether insufficient for the protection of metal rods against a serious fire." Now I may say in a word that in actual practice 1 in. thickness is certainly sufficient for the small sections, and a greater thickness is given for the larger sections. To illustrate what I mean, if 2 in. thickness is required for a bar 1¾ in. in diameter, then surely 1 in. is more than ample for a bar 5-16th in. in diameter.

The rules of the Fire Offices Committee seem to meet this aspect of the matter by providing "that no rod or bar shall be nearer the face of the concrete than double its diameter, and that such thickness of concrete shall not be less than 1 in. and need not be more than 2 in." A very interesting suggestion was also made to the effect that the outer skin of the concrete might be made with a different concrete with an aggregate of high fire-resisting qualities. To carry this out in actual practice would, I fear, involve considerable additional expense.

The Congress passed a resolution as to the nature and size of the aggregate (which should be able to pass 1-in. mesh), the nature and fineness of the cement, and as to the method of protection of angles with angle irons, with all of which I am in complete agreement.

I also understand that the British Fire Prevention Committee are about to undertake a full set of tests to determine the different values of various aggregates in concrete for fire resistance, and as you are aware this body has already made and issued the results of a large number of tests on this subject.

FIRE TESTS.

This research work is very valuable, but these tests as regards concrete have always struck me as requiring a good deal of careful consideration. I do not suppose that any of the various concretes subjected to these tests is older than, say, three months. Now, at that age the concrete must still in the heart contain considerable moisture, and under the application of intense heat this imprisoned moisture will become converted into steam, and everyone knows the expanding properties of steam, which will, I think, tend to the disintegration of the practically still "green" concrete. If a porous aggregate has been used, such as the clinker of destructor refuse, the steam will probably find a ready means of escape, or the moisture will sweat out under the application of heat without becoming converted into steam. But in the case of a dense gravel concrete, the steam will not on account of the density of the mass be able to find a ready means of escape, and will tend to disintegrate the concrete. I do not think this will be evidenced by actual bursting of the concrete, but rather by a large number of small fissures being opened up, separating the mass, and causing pieces to fall off on the application of a powerful jet of water.

Now in a building which has been constructed for, say, a year, this moisture would have almost entirely disappeared, and as time goes on would become more and more infinitesimal, and the conclusion to be deduced from this is that the resistance of gravel concrete to the action of fire will increase with age. I venture to offer this suggestion for consideration, as it seems to me that this may have a considerable bearing on the results of tests made on what is practically "green" concrete. *(Various examples of fires follow here.)* . . . .

Turning now to the rules of the Fire Offices Committee, which apply to this class of construction, I have one or two remarks to make.

FLOOR THICKNESS.

It is provided that no floor must be less than 5 in. in thickness. Two or three years ago the minimum thickness for floors was 6 in. Since the issue of these rules this has been reduced to 5 in., and I hope that the minimum thickness may ultimately be reduced to 4 in.

My reason for expressing this hope is that in economy of design the designer is considerably hampered by this rule, for there is in the design of such work an economical means between the relative proportions of concrete and steel employed, and in the majority of cases 4 in. thickness of concrete, with a slightly larger proportion of steel, is more economical than 5 in. thickness with less steel. In both cases the insulation of the embedded steel is complete, for the floor bars are always of very small cross sectional area, rarely exceeding 7-16th in. in diameter. There is also another important point as regards economy of design in connection with this rule to which I would draw your attention—namely, the considerable difference in deadweight between a 5-in. thick and a 4-in. thick floor. As is well known, concrete is a very heavy, dense material, weighing approximately 1¼ cwt. per cubic ft. The result is that the designer, being forced to increase the thickness for the floor beyond what is necessary for actual strength coupled with economy in design is, by reason of the increased deadweight involved, also forced to increase the strength of all supporting beams, columns and column bases. This is a serious consideration as regards capital cost, and it of course becomes accentuated in proportion to the height of the building. I think the Fire Offices Committee might take this into consideration. I am confident that in many risks a 4-in. floor will form an effective horizontal fire break, especially in cases where the building is well cut up by horizontal fire breaks in the shape of floors, and vertical fire breaks in the shape of internal party walls.

It is unfortunately the case that in almost every instance fire-resisting construction has to fight for adoption against the much cheaper ordinary non-fireproof construction of stone or brick walls with wood floors and wood and slate roof, and I think it must in the long run be greatly to the advantage of the insurance offices that fire-resisting construction be adopted, especially for the heavier risks. It would seem to me very much better that a building should be constructed with fire-resisting floors 4 in. in thickness rather than combustible wood floors. But the tendency of the rule as to minimum thickness is to increase initial capital outlay (so far at least as reinforced concrete floors are concerned) to such an extent that the proprietor may ultimately decide to do without fire-resisting construction altogether, and perhaps this important aspect of the matter might well be given further consideration by the insurance offices, with a view to giving every possible encouragement to the more general adoption of better and safer methods of construction.

INTERNAL DIVISIONAL WALLS.

. . . With reference to internal party walls intended to act as "fire-break" walls, the rules stipulate that these shall not be less than 13 in. in thickness.

It seems strange that 5 in. thickness should be recognised as being sufficient for a horizontal "fire-break" in the shape of a floor, and that for a vertical "fire-break" in the shape of an internal party wall, a thickness of 13 in. is asked for. If 5 in. thickness will act as an effective "stop" in the case of a floor, it will surely do so in the case of a wall.

Perhaps it may be thought that a reinforced concrete wall of this thickness would not resist a lateral thrust, such as a blast of flame or heavy articles falling against it. Such, however, is far from being the case. On the contrary, the resistance of a reinforced concrete wall to lateral thrust and pull is very great.

POLICY OF INSURANCE OFFICES.

. . . There is a continual struggle for adoption between fireproof and non-fireproof construction, and there can be no doubt that the advice and attitude of the insurance offices are considerable factors in determining the result.

I am aware that many insurance officials formerly held the view that "fire prevention" is of no interest to them, and that their business is to rate risks as they find them. I do not know whether this is the view held in the present day, but I hope it is not, because, as I have said, the influence of the insurance offices is so great that much can be done by them concurrently with regard to their own financial interests to diminish the annual fire waste in the country, and surely this is the higher side of the business.

Another factor in the slow progress of fire-resisting construction in this country is that perhaps but few architects have time to make a special study of this branch of work.

The designing of a structure intended to be fire-resisting, and where a severe fire risk resulting from the occupancy or from exposure is generally always involved, seems to me to demand not only a knowledge of special constructional work, but also of the fire risk arising out of the intended occupancy, and neither of these subjects is a matter of every-day experience or interest to the majority of designers. The consequence of this is that the summit of most efforts towards design of fire-resisting buildings is the specification of some commercial firm's "patent fireproof floor," and the type of floor selected is generally ruled by which firm offers the cheapest price, and not by the merits of the floor.

Under such circumstances many buildings have been constructed and designated "fireproof" when, in point of fact, some of them are really as far from being "fireproof" as any ordinary building is, and this has been clearly demonstrated on many notable occasions. To such an extent has this taken place that it has been said that it is impossible to construct a really "fireproof" building.

As I have endeavoured to indicate this evening, it is, however, quite possible to construct "fire-resisting" structures of a very high standard, but it is not the specification of certain details that will ensure efficiency in this respect, but rather the skill and knowledge of the general designer.

If, in conclusion, I may venture to make a suggestion, it would be that the Fire Offices Committee might give consideration to the creation of a standing sub-committee, to whom all questions on fire-resisting construction should be referred. Such standing sub-committee, aided by the expert advice of competent permanent officials, could largely supersede the present hard and fast rules, and give skilled attention to each individual case and its special requirements and merits.

I would suggest that such a committee might, through its officials, undertake :—

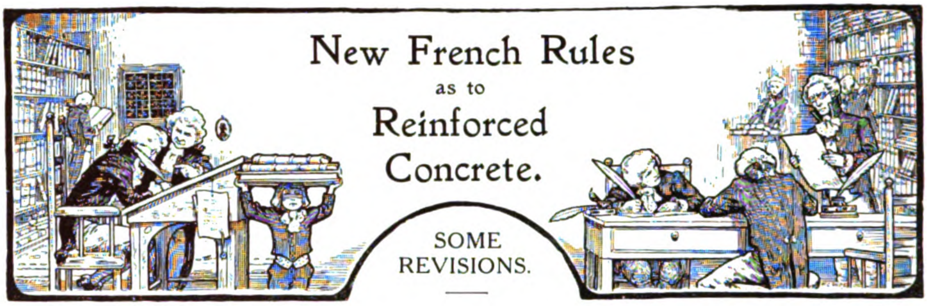
(1) Examination of all architects' and proprietors' plans and specifications submitted to them for buildings proposed to be erected where fireproof construction is intended to be incorporated in the design, and report on such designs to the particular office interested.

(2) Fix discounts for complete "fire-resisting" buildings on the report of the office interested, on the merits of the type of construction employed, details of construction, occupancy limitation of areas, exposure, &c., &c. Such discounts to be tariff.

(3) General research work and accumulation of data on fires and fire-resisting construction.

Perhaps this is too bold and progressive a suggestion to make, but I am convinced that the expense of the establishment of a central department specially devoted to this work would be repaid many times over in the first two or three years of its existence.

Not only this, but it would make for the good of the general community on account of the diminution of the annual fire waste which would certainly ensue and the consequent annual national saving of wealth.



New French Rules as to Reinforced Concrete.

SOME REVISIONS.

Copyright 1907, in the United States of America, by Robert W. Lesley, Phila., U.S.A.

The additions and corrections presented below should be read in conjunction with our previous articles giving a translation and notes on the New French Rules, which after various revisions are now finally in the hands of the French public.—ED.

In our November issue of 1906 we gave an early version of the New French Rules as to Reinforced Concrete, which the technical world had been awaiting for so long, and, as indicated before, we attached so much importance to the Rules, which were accompanied by a circular, that we endeavoured to give the earliest possible intimation to our readers, and chose to risk their confirmation and any possible minor errors.

Last year great difficulties were attached to obtaining the final and correct version, for it would appear that some errors had crept into even the final version signed by the authorities of France, and that certain alterations had to take place before the document could become public property. Even to-day we venture to intimate that there are one or two typographical errors in the document.

All these minor points have now had our consideration, and, having regard to the importance of the subject, we are presenting a list of revisions and corrections which should be compared with our previous articles—or, better still, the previous articles should be corrected up to accord with the final changes, which we believe will enable our readers to appreciate exactly the meaning of the new Rules in their finally revised form.

We should also intimate that we have taken this opportunity to alter and improve our previous version where we think the translation could be improved.

The following notes are divided into three sections, relating respectively to:—

1. The Instructions for the Design of Structures in Reinforced Concrete.
2. The Circular explaining the Instructions.
3. The Report of the Commission of the Ponts et Chaussées.

INSTRUCTIONS RELATIVE TO THE EMPLOYMENT OF REINFORCED CONCRETE.

Page 332.

Art. 1, *line* 6.—Instead of "steel girder bridges" substitute the more general expression "metallic bridges," which, of course, covers every form of iron and steel bridge design.

Art. 2, *l.* 3.—Instead of "as far as possible" read—after the word "treated"—the phrase "unless exceptions are justifiable." In this case the report is very positive and does not authorise either partial compliance, nor non-compliance unless some very good reason can be adduced.

Art. 3, *l.* 2.—Instead of "tanks" read "the walls of reservoirs," and instead of "water mains" read "conduits," a term which applies to sewers as well as to water pipes.

Art. 4, *l.* 3.—For "$\frac{2}{7}$" substitute "28 per cent." (See p. 464, Jan. issue.)

Art. 5, *l.* 1-3.—Substitute the following translation: "When the concrete is hooped, or when the transverse or oblique reinforcement with which it is provided is disposed in such manner as to prevent more or less efficaciously the swelling of the concrete under the influence of the longitudinal compression to which it is subject."

Art. 5, *l.* 11.—Instead of "$\frac{3}{5}$" substitute "60 per cent."

Art. 6, *l.* 1.—Before "slipping" insert the word "longitudinal."

Art. 6, *l.* 4.—For "may be" substitute "shall be."

Art. 7, *l.* 6.—Instead of "and especially for" substitute "such as."

Art. 7, *l.* 8.—Instead of "$\frac{5}{12}$" substitute "40 per cent."

Art. 9, *l.* 3.—For "most unfavourable" read "maximum."

Art. 9, *l.* 6.—For "expansion and contraction of the concrete" read "shrinking of the concrete." This correction is justified by the fact that expansion and contraction are considered in the preceding phrase dealing with changes of temperature, the shrinking here intended evidently being the contraction which accompanies the process of hardening in air.

Page 333.

Art. 12.—The text now reads thus: "For compression members the designer shall assure himself whether they are or are not liable to flexure. Nevertheless, inquiry into this point may be dispensed with for members of which the ratio of length to the least transverse dimension is less than 20, and in which the compressive stress does not exceed the limit defined by Art. 4."

Art. 13.—In the Report this article (to the same effect as the second paragraph of Art. 19 in our translation) is included under the head of Calculations.

Arts. 13-20.—Arts. 13 to 18 in our translation of the draft are numbered 14 to 19 in the report, and Arts. 19 and 20 in our translation correspond with Art. 20 in the report.

Art. 13, *line* 2.—"Fixing in position" more accurately conveys the meaning of the original word than "disposition," which might possibly be thought to refer to the arrangement, or distribution of the reinforcement.

Art. 14, *l.* 7.—As metrical units are employed elsewhere in the translation it is better to say, as in the original, "5 centimetres" (1·968 in.), instead of "2 in."

Art. 15, *l.* 9.—Instead of "$\frac{3}{4}$ in." read "15 to 20 mm." (0·59 to 0·78 in.).

Art. 20.—The following is a literal and preferable translation: "The removal of the moulds and centering shall be performed without shocks by purely static forces and only after the concrete shall have acquired the resistance necessary for sustaining without injury the stresses to which it is subjected."

Art. 21, *l.* 3.—The sentence commencing on this line should read: "The conditions of the tests as well as the time that shall elapse before the structures are brought into use shall be inserted in the contract conditions. The maximum deflections which must not be exceeded shall also be inserted, at least as far as practicable, in the contract conditions."

Art. 22.—The meaning of this paragraph is rendered somewhat more clear by the literal translation: "The engineers shall take advantage of tests to make not only all measurements of deformation or of verification of the conditions specified in the contract conditions but shall also take as far as possible such measurements as are likely to be of scientific interest to engineers." The following sentence should be added: "For works of any importance registering instruments shall be employed."

Art. 25, *par.* 1.—The test loads defined in the report are "the specified loads and superloads," and they are to be applied "either over the whole area of the floor or at least over one complete panel."

EXPLANATORY CIRCULAR.

Page 334.

A., *par.* 4, *line* 3.—For "sinking" substitute "failure," as the circular does not intend to imply the settlement but the collapse of a building.

Art. 4, *l.* 3.—For "$\frac{2}{7}$" substitute "28 per cent." (See p. 464, Jan. issue.)

L. 32.—For "45·7 kg., 51·4 kg., and 57·1 kg." read "44·8 kg., 50·4 kg., and 56 kg." (See p. 464, Jan. issue.)

L. 46.—For "Otherwise the engineers" read "Government engineers."

Art. 5. *l.* 5.—For "buckling" read "swelling" or "lateral expansion."

L. 13.—After "transverse" add the words "or oblique." The next sentence should read: "It would be difficult to give an absolute indication in this respect." The succeeding sentence requires amendment as follows: "Some comparative tests made in the laboratory and the workshop upon concrete without transverse reinforcement and also with such reinforcement and indicating the augmentation of resistance to crushing caused by the latter, permit the determination of the corresponding augmentation which may, without danger, be adopted for the safe working stress."

Page 335.

Line 8.—For "at least" substitute "at most."

L. 22.—"The former indications" are those given in the previous paragraph of Art. 5.

L. 25.—For "$\frac{3}{5}$" substitute "60 per cent."

Footnote, *l.* 7.—For "buckling" substitute "swelling," as before.

Page 336.

Col. 1. *line* 7.—Read "The required centre of gravity of the hypothetical section Ω" instead of "The centre of gravity of the hypothetical section Ω to be ascertained."

L. 12.—Read "$Y_c = G_cK$"; not "$Y_c = GK$."

L. 17.—After "gives the ordinate" insert "y."

Formulæ 2-5.—These formulæ should be numbered $2'$, $3'$, $4'$, $5'$, and 5^a.

Col. 2, *formula* 11.—For "$n_s =$" read "$n_c =$."

Page 337.

Col. 1, *line* 4.—Insert "11" to indicate that the succeeding comments relate to Art. 11 of the "Instructions."

Col. 1, *par.* 5.—For the sentence commencing "The engineers" read the following: "The administration may accept the usual assumption, although this is not strictly accurate, that for concrete in tension the value of the coefficient of elasticity is the same as for concrete in compression."

Par. 7, *l.* 2.—For "features" substitute "elements."

L. 5.—For "by a" substitute "the."

L. 12.—For "as the reactions over the supports" read "as also the reactions of the supports."

Par. 8, *l.* 6.—The expression "$-\frac{pl^2}{12}$" is indicated in the Report as formula (14).

L. 8.—The expression "$\frac{pl^2}{24}$" is indicated in the Report as formula (15).

Col. 2, *par.* 4, *l.* 17.—The sentence should read: "However, the engineers may adopt this method of procedure if they consider it more satisfactory."

Page 338.

Col. 1, *line* 5.—For "pressures of concrete" substitute "compressive stresses in the concrete."

For "if *m* is neglected" substitute "to the factor *m* nearly."

L. 6.—For "pressure of the compressive reinforcement" substitute "stress in the compressive reinforcement."

L. 8.—Read "Let K be the angular coefficient of the straight line B′XA′, or the trigonometrical tangent of the angle B′XB."

Fig. 3.—Above the letter A insert the letter *a* on the same level as the letter *a′*.

L. 13.—For "*O*" substitute "o."

Formula 16.—For "*O*" substitute "o."

Formula 17.—At the end of the first line of this equation insert *d* thus: "$+m\omega\ (y_1 - d)\ d$."

Formula 18.—For "$O=$" substitute "o=."

Formula 21.—Just before this formula read "R'_5 of the reinforcement will be."

Formula 22.—In the first line of this formula read $\left[\frac{c^2}{2}y_2 + \frac{c^3}{3}\right]$ instead of

$$\left[\frac{c^3}{2}y_2 + \frac{c^3}{3}\right]$$

At the end of the formula insert "=o."

Formula 23.—Instead of "$=c$" substitute "=o."

Formula 25, *line* 2.—After $(-c+\epsilon)$ read "y_2" instead of "½."

On the line after the formula substitute "number" for "term."

Formula 26.—There are two formulæ here, which are numbered (26) and (27) in the Report.

Line 54.—The following is an exact translation of the paragraph commencing on this line according to the revised copy of the Report:—

"Finally, in the case of a slab, to ascertain whether the neutral axis falls inside the rib or the slab, it will suffice to ascertain whether the first term of equation 23 has or has not contrary signs at the two extremities of the rib."

Formula 27 taken from the draft circular comprises two separate expressions, neither of which is an equation as printed, and "=o" should be added at the end of each.

Page 339.

Formula 28.—For "C" read "*c*".

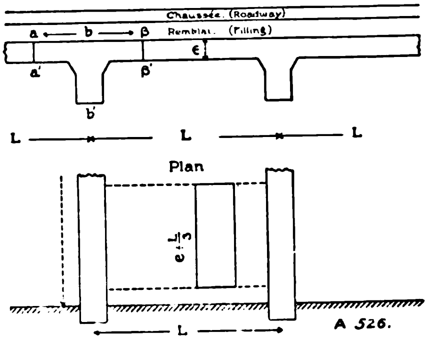
Fig. 4.—We now give an exact copy from the Report of the two diagrams included in this figure, so that the reader may be enabled to appreciate better the remarks which it is intended to illustrate.

Line 23.—For "L" read "*l*."

L. 25.—After "spacing" insert "L."

Par. 4.—The following translation better conveys the meaning of the original: "As regards the floor itself, if it has to support concentrated loads between two ribs, two series of horizontal reinforcing bars should be provided, one series at right angles to the other. As a general rule the total sectional area (per metre width of the slab) of the transverse reinforcement should be equal at least to one-half the sectional area (per metre length of the slab) of the longitudinal reinforcement."

L. 38.—For "embankment" substitute "filling." (See new copy of *Fig.* 4.)



After "roadway" insert "which it carries."

L. 46 *and* 47.—These two lines should read: "beam of rectangular section $\left(c+\frac{L}{3}\right)\epsilon$, and of span L, supported upon two consecutive ribs."

L. 48.—Delete "right-angled."

L. 49.—After "ribs" insert "at right angles to one another."

Col. 2, *l.* 17.—Delete "for."

L. 22.—After "in" insert "their."

Page 340.

Art. 12.—This article has been altered (see p. 404, Jan. issue). It should be noted, however, that in our original translation there are two typographical errors—namely: "1,000" instead of "10,000," and "ω" instead of "π."

"III.—Part IV." should read "Parts III. and IV."

III. Part IV., *l.* 7.—For "bad selection" read "inferior quality of the materials."

L. 8.—For "or preparation of materials" read "or to their improper employment."

L. 10.—For "clearness" read "purity."

L. 13.—For "correct disposition" read "secure fixing," the latter expression conveying a better idea of the meaning intended by the Commission.

REPORT OF THE COMMISSION APPOINTED BY THE CONSEIL GENERAL DES PONTS ET CHAUSSÉES.

Page 461.

Par. 3.—It should be noted that (as stated on p. 473 of the Report) the value $m = \frac{1}{10}$ applies only to concrete consisting of 300 kg. Portland cement, 400 litres sand, and 800 litres gravel.

Par. 3, *line* 3.—The phrase commencing with "Although the value" should read "In Switzerland and Germany, as also by French and Belgian authors, the value 15 is adopted in preference."

Par. 4, *l.* 1.—For "Instructions" substitute "Explanatory Circular." For "assumption" substitute "proposition."

Page 462.

Line 9.—For "Instructions" read "Explanatory Circular."

L. 11.—After "Article 5" insert "of the Instructions". For "function" substitute "coefficient."

L. 13.—Read "the coefficient m' being obtained in each case according to the rules indicated in the Explanatory Circular."

L. 17.—For "62,645 cm^3" read "62.645 cm^3."

Table I., col. 4.—In test (1) for "161" read "168."

In test (5) for "100" read "190."

Col. 5.—In heading for "$4\frac{wd^2}{400}cm^2$" read "$4\frac{\pi d^2}{400}cm^2$."

Table II.—The heading of col. 2—exactly reproduced from the Report—is misleading. The figures in this column are values of $15w$, and not $15w \div cm^2$. The idea of the Commission was evidently to convey the meaning that the sectional area of reinforcement is expressed in square centimetres. They have chosen, or more probably their printers have chosen for them, a not altogether happy way of carrying out the idea in question.

Multiply the results in col. 4 by 1,000, as in our advance copy of the Report a decimal point was used, in accordance with the French practice, instead of a comma to denote thousands.

Page 463.

Line 8.—For "Instructions" read "Explanatory Circular."

For "figures" substitute "values of m'."

L. 10.—The sentence immediately below Table III. should read: "Again, assuming in round figures, according to Article 4 of the Instructions." For "function" substitute "35 kg. allowed above and amplifying this stress in accordance with Article 5 by the coefficient $\left(1+m'\frac{V'}{V}\right)$."

Lines 14-16.—The two sentences here printed are not correctly translated. Immediately after formula (B) we have in the original the explanation applying thereto as follows: "In accordance with the rules indicated in the Explanatory Circular we are led to take for m' the values given in the table below." (Table III.)

Next follows the sentence: "The loads N which the column is capable of supporting will be given by the formula:—

$$\text{“}N = R_c(625 + m\omega) \qquad (B')\text{.”}$$

Table III., col. 2.—For "m" read "w." which is the correct heading.

Col. 3.—The heading is simply "$m\omega$"; "cm^2" merely indicates that the values are in square centimetres.

Col. 5.—For "$0^m.52$" read "$0^m.25$."

Col. 8.—For "$4m'\frac{V'}{V}$" read "$\left(1+m'\frac{V'}{V}\right)$."

The complete heading reads:

$$R_c = 50\left(1+m\frac{V'}{V}\right)$$

Col. 9.—Above the values insert "kg." and multiply all the figures by 1,000 for the reason stated in connection with col. 4 of Table II.

"MODIFICATION OF THE EXPLANATORY CIRCULAR."

Page 464.

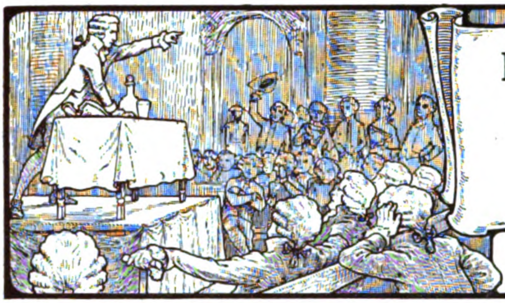
Col. 2, *formula* 31.—For "ω" substitute "π."

Line 13.—For "if we take" substitute "with."

L. 25.—For "$\frac{M}{I}$" substitute "$\frac{Mv}{I}$".

For "formula 5" substitute "formula 5a."

Formula 33.—For "V_oV" substitute "v_ov."



Reinforced Concrete at the Engineering Conference

London, June 1907.

THE THREE PRINCIPAL PAPERS.

We are presenting extracts from the three principal contributions on Reinforced Concrete, put forward at the Engineering Conference, held in London on June 19th to 21st. These contributions are all three from Engineers who have had practical experience in Reinforced Concrete work. The three papers have useful points for Engineers who are conducting reinforced concrete work, and merit close attention.

Exigencies of space unfortunately prevent our printing these papers in full, giving them a more important place in this issue, or from commenting on them as we would wish.

One general observation we should however, make, namely, that the uniform nomenclature of "reinforced concrete" should have been used at this Conference, instead of the diverse descriptions of "ferro" concrete and "armoured" concrete, etc.—ED.

THE DURABILITY OF REINFORCED CONCRETE STRUCTURES.

By F. E. Wentworth-Sheilds, M. Inst. C.E.

(*New Dock Works, Southampton.*)

THE chief things which we should expect to shorten the life of reinforced concrete are:—

(1) Settlement of foundations.	(3) Atmospheric change (rust, etc.).
(2) Fire and earthquake.	(4) Abrasion and collision.

1. ***Settlement of Foundations.***—Dealing first with settlement of foundations, it may be said that steel concrete is a rigid material, and the foundations of a structure of this substance ought to be designed in such a way that they cannot settle. This can always be done even on soft ground, either by piling or by spreading the weight over a large area, on a strong reinforced-concrete base. An instance of the evil of neglecting this precaution was to be seen at the Kom Ombo pumping-station in Upper Egypt last year. A culvert of reinforced concrete 10 ft. in diameter was laid in the Nile silt. The ground had evidently been disturbed beneath it, and the culvert settled down, producing transverse cracks in the concrete. The water escaping from these cracks no doubt aggravated the settlement, and by the time the culvert came to rest the leakage of water was so serious as to necessitate its being abandoned.

2. ***Fire and Earthquake.***—Reinforced concrete is undoubtedly a first-rate fire resisting material. It would seem that for fire-resisting purposes it is best that the steel should consist of many bars of small section in preference to few bars of large section, as the first arrangement forms close network, which prevents pieces of concrete from dropping out and so reducing the strength of the building. It is also important the concrete aggregate should be crushed small. The ideal composition for the aggregate would seem to be a strong flint or granite for the hearting, with an outside skin of cinder concrete to act as a good non-conductor. It is essential, too, that in a building the walls, floors, and posts should be well tied into one another

There is a tendency nowadays, in designing steel-concrete buildings, to reject that material for the walls on the score of expense, using it only for floors and columns. Sometimes a compromise is made; for instance, at the tobacco-warehouse now being built at Bristol on the Coignet system, the walls consist of a framework of steel-concrete with brick panels. This is probably the best arrangement, as although brickwork is undoubtedly more economical for walls than steel-concrete, still the latter is much less inclined to collapse under fire. The brickwork can be arranged, as at Bristol, to conceal the concrete entirely, but the collapse of any part of the brickwork would not endanger the floors or the concrete framework.

With reference to damage by earthquake. Captain Sewell, in a recent magazine article (CONCRETE, of September, 1906), gives an excellent account of its behaviour at the San Francisco earthquake. One building received a very severe shaking, and while the brick wings were in a state of collapse the damage to the steel-concrete wing was insignificant.

3. ***Atmospheric Change.***—We have had enough experience of concrete to know that, if good, it is practically unaffected by atmospheric changes. At one time it was feared that the steel might rust, especially in structures under water, but this fear seems to be groundless. Some recent experiments on the permeability of concrete by Mr. Baldwin Wiseman show that, if well made, it is one of the most water-tight materials known, and that it rapidly becomes less and less porous when water is forced through it. A recent examination of three steel-concrete quays at Southampton standing in water convinced me that there was nothing to fear on this score, provided of course that the concrete is not accidentally knocked off and that it is of good quality.

Some experiments recently raised the alarm that steel rods immersed in damp concrete rust rapidly when mild electric currents are passed through them. To this the best answer is that well-made concrete should not be and generally is not damp. It will have been noticed by those who have had to cut out good steel-concrete work that, although recently immersed in water, the concrete and steel were both dry and clean, and that the water appeared unable to penetrate even the inch or two of concrete which covered the steel. However, the risk should not be overlooked, and care should be taken to exclude electric currents from steel-concrete work as much as possible.

4. ***Abrasion and Collision.***—It has been stated that steel-concrete has far more resistance to abrasion from shipping or other floating objects than timber, but my experience at Southampton convinces me that this is quite exaggerated praise. On the contrary, if reinforced concrete is to be used for marine work, it must be carefully fendered at all parts where it is likely to be struck. In most systems of reinforced concrete the steel is placed within an inch or two of the surface, and if the structure is not protected by timber cushions, this concrete skin is easily knocked away, leaving the steel naked and liable to rust. At the same time it is true that steel-concrete does not spall easily from blows, provided they do not fall directly on the concrete, and it will stand a wonderful amount of shocks, and bending due to shocks, if a wooden fender is interposed.

The coaling-jetty at Southampton (completed 2½ years ago) suffers as much perhaps from the blows of ships and barges as any steel-concrete structure yet made. It is protected by fenders of American elm, and in spite of blows which have caused the whole jetty to sway, there is no sign as yet of the concrete spalling off, except at one or two places where the blow has fallen directly on the concrete.

Speaking of this jetty calls to mind an interesting piece of repair-work which was carried out there about two years ago. A steamer collided violently with the quay, breaking two piles and the beams they supported. On examination by divers it was found that the piles were broken down to a level of 12 ft. below low water. The work of repairing the quay, however, turned out to be fairly simple; the broken concrete and steel rods were cut away by divers, who also erected new rods to take their place. These new rods were joined to the undamaged part of the old ones by steel tubes, and the stirrups or binding wire were placed round the new rods at correct intervals. A water-tight casing of timber was then placed round the pile, which extended from the undamaged portion to above low water. From this casing the water was pumped out and the concrete was filled and rammed into the box in the ordinary way. Above low water the piles and beams were remoulded in just the same way as they had been originally built. This shows how easily and effectively steel concrete can be repaired.

Conclusion.—On the whole, it may be said that our experience goes to prove that reinforced concrete, if well designed, is likely to be one of the most durable building materials—if not the most durable—that can be found.

"FERRO-CONCRETE" STRUCTURES.

By Charles Scott Meik, M. Inst. C.E.

My experience of the construction and durability of ferro-concrete has been gained chiefly in connection with piers and wharves, particularly a pier at Purfleet (see CONCRETE No. 3, Vol. I., p. 176) on the Thames, built for the purpose of discharging coal from steamers into craft in the river or wagons on the pier, and the reconstruction of a pier in Italy.

Form of Steel Bars.—The form of the section of bars, provided the area is sufficient, is of little moment, the friction of the steel in the concrete varying but little in all cases. A little rust on the bars is no objection, as it increases the friction.

The round bar offers most facility for getting the steel thoroughly embedded in the concrete.

The stirrups, or iron bands for holding the round steel bars in place, must be so formed as not to give until the limit of elasticity has been reached. At Purfleet those first used stretched owing to not being efficiently connected, and under test a section of pile crushed prematurely owing to the round steel bars buckling outwards at the centre. The object of the use of the stirrups is to prevent this. The test-piece above referred to was part of a 14-in. pile, 5 ft. in length, which crushed under a stress of 221 tons, or 1·13 tons per sq. in.

An improved form of stirrup was subsequently used which increased the strength of the pile or column to a large extent. The round bars in the framework of the pile must also be efficiently strutted by diagonals to hold it rigid until the concrete mass has set hard in and around the framework of steel.

Concrete Aggregates.—It is necessary to crush the aggregates of the concrete small enough to pass through a mesh of ⅞-in. diameter, in order to permit the concrete to get into all the interstices of the steel framework, and, in order to ensure this, the concrete should be well rammed in with suitably shaped rammers. The ramming of the concrete does not have much effect on its strength after it has been made for 12 months. Experiments of blocks 12-in. cube prove this.

A cube of 12 in. of rammed 4-to-1 concrete edge, crushed at 265 tons, or 1·84 ton per sq. in., and a similar cube of 4-to-1 concrete made in the ordinary manner failed at 258 tons, or 1·80 ton per sq. in. Both blocks were 18 months old at the time of testing.

Strength of Concrete.—The ratio of cement to aggregates should be between 5 and 6 to 1 for ordinary beams and floors and 4 to 1 for piles and columns to carry heavy weights. In the upper end of piles, for a length of 1 ft., it should be 3 to 1.

Piles.—Considerable difficulty was experienced in driving the piles at Purfleet to the required depth into the Thames ballast forming the river-bed, the specified set being 1 in. for ten blows of a 30-cwt. monkey falling through 6 ft.. This set was frequently obtained before the piles were down to the required depth by 3 or 4 ft., taking in some instances 4 or 5 hours to get down, some being severely punished and broken at the top. These piles were all driven with the Hennebique cap. fitted with a cushion of sawdust, which requires to be renewed one or twice if the piles drive hard, as they did in this case.

For driving into rough gravel or ballast the piles should be at least six weeks old, and should have a tube down the centre, for the application of a high-pressure water-jet.

Test piles of pitch-pine were driven into the river-bed before the ferro-concrete work was commenced, at a short distance from either end of the pier, and the set of these at about 24 ft. below the surface of the ground was 1 in. to five blows of a 20-cwt. monkey falling through 9 ft.

The set of a concrete pile in similar material varied from ten to forty blows to 1 in. of set with a monkey weighing 2 tons and falling through 4 ft., which was the test substituted for that referred to above after it was found that the driving was very hard.

Decking.—The ferro-concrete decking acts as a horizontal girder and enables all horizontal diagonal bracing to be dispensed with. The pier was subjected to a severe strain by the collision with it of a large steamer in January last. I attribute the reason of so little damage being done to the pier to the stiffness due to this horizontal decking.

Vibration.—The vibration of a pier supported on piles is nearly as great as a pier made of timber piles, but this has no bad effect on the structure, judging by the experience gained at Purfleet.

Action of Sea-Water.—My experience, so far as it extends, proves that the deterioration of the steel in the concrete, provided the latter is properly made, is a negligible quantity. Numerous rust-marks have appeared on the piles in the pier at Purfleet since its construction, but the greater number of these are due to nails which have accidentally got mixed in the concrete and are imbedded in it close to the surface. In the few cases where the water has gained access to the steel bars there has been no difficulty in cutting out the defective concrete and making good with cement.

Cost.—At Purfleet the cost of piles was about 5s. 6d. per cubic ft., bracings about 5s. per cubic ft., and the decking was 20s. per sq. yard.

The cost of the pier proper on which the cranes are placed worked out to 17s. 8d. per sq. ft. of surface, and that of the pier approach to 10s. 2d. per sq. ft. These prices are on the high side, however, owing to the great height from the decking to the points of the piles, as much as 70 ft. in some instances, and also to the fact that the pier was designed to carry very heavy loads. On the other hand, the price for piles was low if the difficulty of driving them into the compact Thames ballast is taken into account.

Concrete v. Timber.—Ferro-concrete is to be preferred to timber for marine structures, as it is immune to the attacks of the sea-worm; on the other hand, timber is easier to repair when damaged by collision.

As regards cost, ferro-concrete is about the same price as greenheart timber, while it is about 1s. to 2s. per cubic ft. dearer than pitch-pine at its present price.

REINFORCED CONCRETE RAILWAY STRUCTURES.

By C. A. Harrison, D.Sc., M. Inst. C.E.

(*North-Eastern Railway.*)

Concrete of itself, as you are aware, has been the subject of frequent discussion and probably of more Papers than any other subject in engineering, and from what I have gathered in conversation with fellow-engineers, I think ferro-concrete will be a still thornier question. As far as I have been able to look into the subject, ferro-concrete on one system or the other has been largely used both on the Continent and in America, and England appears to have been rather late in adopting it. Personally I have not built any bridges in ferro-concrete, and therefore cannot speak to the first question, which I wish to put before you—namely, "*What evidence is there that reinforced concrete will withstand the fatigue and stress of railway traffic?*"

The North Eastern Railway Company has built a very large warehouse and also several buildings (among others the offices which I at present occupy) of ferro-concrete, and there is no doubt that they have been less expensive than the old method of brickwork and girders.

Reinforced-concrete construction of buildings will necessarily add to the work of the engineer, for he can design and construct what might be called the framework and only require the architect's aid for the ornamental outside work or embellishment of the interior.

Of course all ferro-concrete depends very much on how it is built up, and also to a very large extent on the use of good material as regards both bars and cement. Given these conditions and with proper calculation of strains, I do not see why a ferro-concrete building should not be at any rate as strong as, if not stronger than, a building of stone or brick.

A combination of steel and concrete undoubtedly affords facilities for the erection of buildings of an exceptionally fire-resisting character; but, to secure this, the effect of fire and water on the material used, both separately and in combination, have to be duly considered and provided for. A building which was of faulty construction and pervious to fire would have to be reconstructed if damaged by fire, as the bars or other metal would be so twisted that it would be impossible to restore them.

Most of the ferro-concrete structures have proved a success, and where they have been failures, as far as I can judge from information I have obtained and articles I have read on the subject, these have been due to bad material, bad workmanship or faulty inspection.

The second point to which I am asked to draw your attention is, "*What evidence is there that the material used for reinforced concrete is not liable to corrosion?*" As far as the information I have goes, it has been found that, unless the bars are very rusty, the oxide or iron in the bars when placed in the concrete produces ferride to a very slight extent round the bars and practically makes the bars quite clean. I am told of instances where piles have been cut off and, after lying about in water, have been broken up, and the bars have been found to be quite bright and clean. On the other hand, should the concrete surrounding the steel or iron be faulty, water gets in, and I am certain, from experience of iron-slag concrete in sea-water, that some chemical action would take place, which would probably render ferro-concrete practically useless.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Standard Cement Specification.—We just hear that the revised British Standard Specification for Portland cement is now available. The following are some of the revisions :—

The percentage of sulphuric anhydride has been slightly raised; the quantity of cement to be used in the test for fineness and the period for which it is to be sifted have been specified; the residue on the finest sieve has been somewhat reduced; the grading for the increase of tensile strength in the heat test has been further extended; the *maximum* final setting time for the slow-setting cement has been increased; and, lastly, the expansion under the Le Chatelier test has been reduced.

We shall deal with the specification fully in our next issue.

The Engineering Standards Committee, like the British Fire Prevention Committee and other similar bodies engaged in research work, lacks funds, owing to the parsimony of a short-sighted Government, and we have a circular before us signed by Sir John Wolfe-Barry, suggesting to the various trade interests concerned in the case of the Engineering Standards Committee that the trades should subscribe towards the expenses of the investigations and standardising, the various trades affected to be assessed for fixed amounts. We trust the Portland Cement trade will support this movement. One firm, we understand, has already given £100.

Reinforced-Concrete Post Office Building.—We learn that it has been determined to utilise reinforced concrete (Hennebique system) for the large new sorting office in Newton Street, Oldham Road, Manchester, to be built to the designs of Mr. W. Pott, F.R.I.B.A., of H.M. Office of Works, and that the contract has been placed in the hands of Messrs. Edmund Nuttall, of Trafford Park, Manchester.

Catalogues. — The Trussed Concrete Steel Co. have transmitted to us for notice a copy of their new booklet on reinforced concrete, containing points concerning the "Kahn" bar.

We consider the booklet (which is in octavo form, and comprises 128 pages extremely well printed) to be an advance upon similar trade booklets of this character that have been recently put before us.

The booklet should be useful not only to the users of the Kahn bars but to all interested in reinforced concrete, more particularly as it contains a well-drafted general specification for reinforced concrete.

Technically, the illustrations of a suspended balcony at Detroit, U.S.A., and of some wide-span floor work at the Western Ohio Bottle Factory, U.S.A., call for special mention.

Our attention has also been called to a handbook of instructions which have been issued by the Detroit office of the same firm, published in 1907, and comprising some 35 pages of most useful notes, particularly applicable to the foremen in charge of new works. These notes could scarcely be improved upon, and the diagrams included are much to the point.

A Correction.—In our issue No. 1, Vol. II., we published an article entitled *Reinforced Brickwork Tanks in our Imperial Possessions,* and we have been informed by the author that the titles under Figs. 2 and 3 are incorrect, and should read in accordance with the text at the top of page 41.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

REINFORCED CONCRETE SWIMMING BATHS AND STORAGE TANK AT CHELSEA.

THREE examples of reinforced concrete construction are described below, these being of more than ordinary interest, for the reason that their design is based upon mechanical principles whose application involves no question of patent rights.

The works in question form part of the new public baths built by the Borough Council of Chelsea, and include a first-class swimming pond 100 ft. long by 30 ft. wide, a second-class swimming pond 96 ft. long by 27 ft. wide, and a water-storage tank with the approximate capacity of 100,000 gallons.

The baths and storage tank form part of the establishment designed for the Borough Council by, and erected under the superintendence of, Messrs. Wills and Anderson, the architects. Mr. A. N. Coles, of Plymouth, was the general contractor, and The New Expanded Metal Co., Ltd., were sub-contractors for the whole of the reinforced concrete construction. The cement used was the "Ferrocrete" brand.

Swimming Ponds.—As shown by *Fig.* 1, the two swimming ponds are situated side by side, the small difference in their length having been necessitated by the angular direction of the left-hand wall of the building by which they are covered. Thanks to the tensile resistance of reinforced concrete, it was practicable to make the walls of the ponds comparatively thin, and to form outside

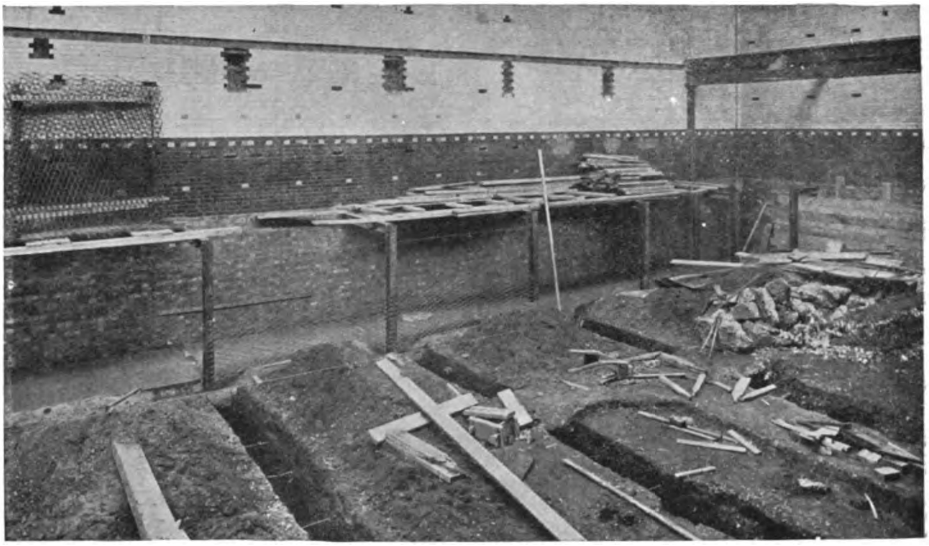
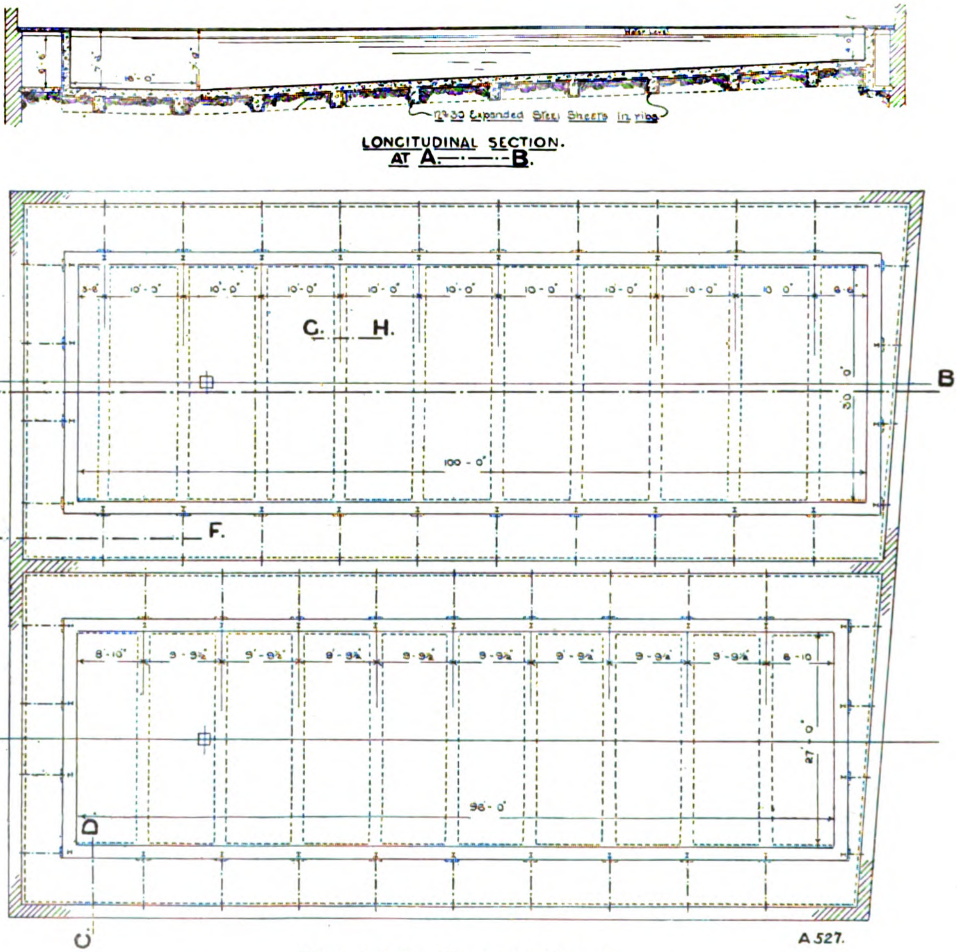


FIG. 3. CHELSEA BATHS.
(General View of First-class Pond, while under construction.)

them a subway running round each pond. The subways afford accommodation and ample facilities for the inspection of the water supply and circulation mains, and provide an assurance that no unsuspected and undetected leakage of water can take place through the walls, as may happen in the case of swimming baths designed in the ordinary manner.

Fig. 2 is a longitudinal section through the middle of the first-class pond, but at the same time it illustrates the general construction of the other bath.



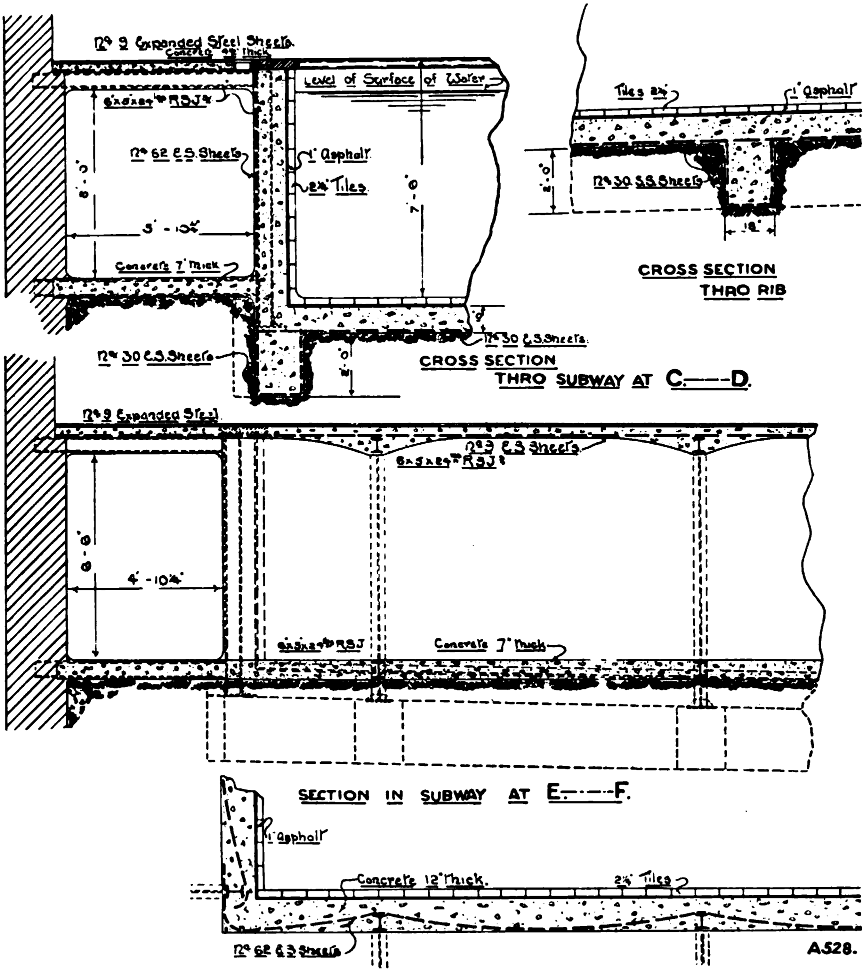
FIGS. 1 & 2. CHELSEA BATHS.

After the site had been prepared conformably with the slope indicated in the section, trenches were excavated for the footings of the walls and the transverse ribs of the bottom slab.

Fig. 3 is reproduced from a photograph taken while the ribbed bottom of the first-class pond was under construction. Several of the trenches are here shown, some with irregular sides as left after excavation, one with the edges trimmed ready for boarding, and one at the extreme left hand with some of the concrete and expanded metal reinforcement in place between the boards used for moulding purposes.

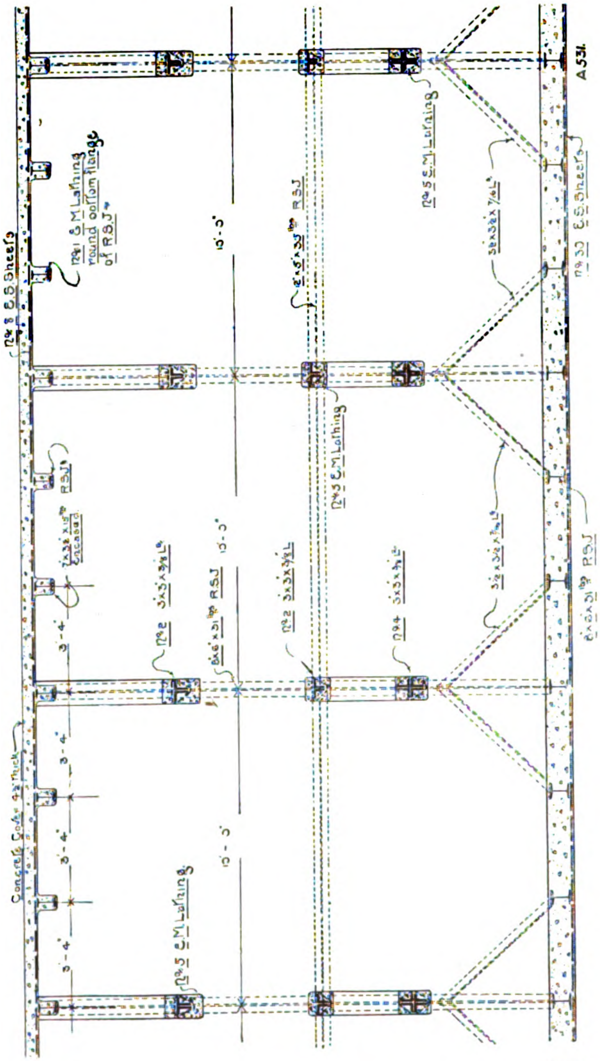
When the ribs had been completed, the connecting slab was moulded on a suitably prepared surface.

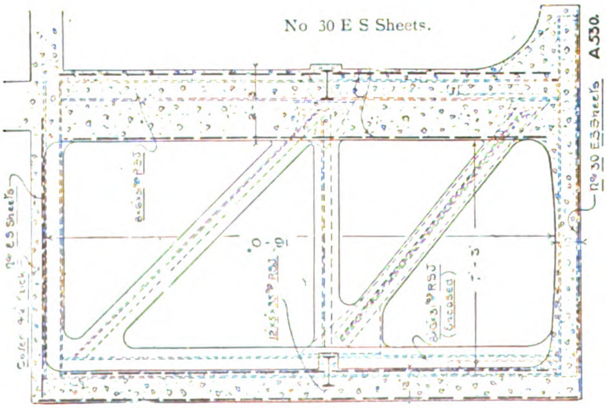
it will be seen that the reinforcement consists of expanded metal, with the addition of 6 in. by 5 in. rolled steel joists in the walls of the ponds, and in the arched roofs of the subways. The joists, where used vertically, take the place of

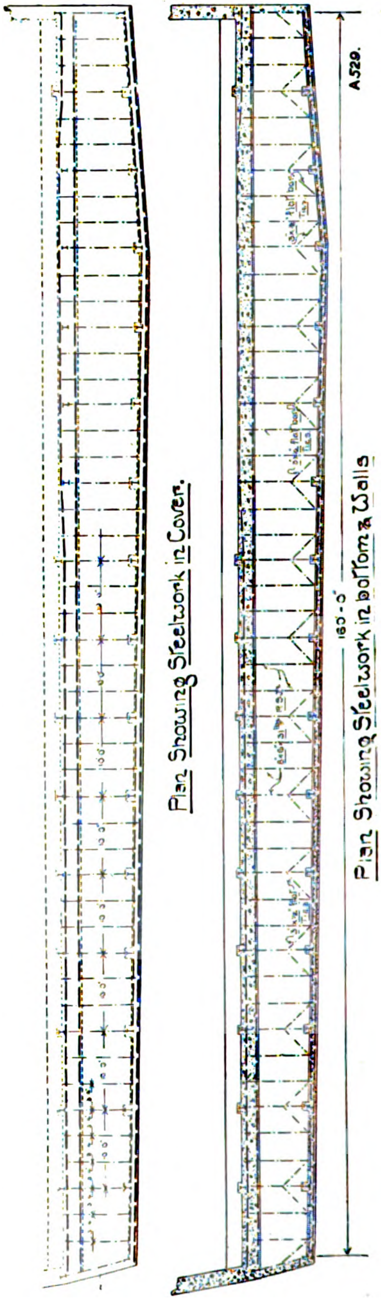


FIGS. 4 TO 7. CHELSEA BATHS.

Details of Reinforcement.—The disposition of the reinforcement is generally represented in *Fig.* 3, but for the benefit of our readers we give in *Figs.* 4 to 7 a series of sections to an enlarged scale. By examination of these detail drawings the reinforced counterforts that would otherwise be necessary for imparting rigidity to the wall construction, and where used horizontally they act as beams for the gangways over the roofs, and at the same time as struts which prevent






Plan Showing Steelwork in Cover.
Plan Showing Steelwork in bottom & Walls
160'-0"
A529

FIGS. 8, 9 & 10. CHELSEA BATHS

outward movement of the walls under the pressure exerted by the water contained in the ponds.

Being subject to very little vertical pressure, the walls require reinforcement chiefly against the tensile stresses developed by outward pressure of the water, the diagram of bending moments in respect of the vertical axis taking the form corresponding with that of a beam fixed at one end and merely supported at the other.

In virtue of the support afforded by the rolled steel joists acting as counterforts, the diagram of bending moments in respect of the horizontal axis of the walls corresponds with that for continuous-beam spans, a fact which is adequately recognised by the disposition of the expanded metal sheets as shown in *Fig.* 7.

After completion of the concrete work, the interior of each pond was lined with asphalt sheeting, 1 in. thick, and finished with glazed tiles 2½ in. thick.

Storage Tank.—A very ingenious use has been made of reinforced concrete in the design and construction of this tank, which is situated beneath the footpath of the street bordering one side of the new baths at Chelsea. The tank has the total length of 160 ft., the average width of 7 ft. 3 in., and the average depth of 16 ft. The bottom of the tank has a slope of about 1 in 8.5 from the right-hand end, and of about 1 in 11.3 from the left-hand end. By the two sectional plans in *Fig.* 8 it will be seen that the width of the tank increases from each end, the maximum and minimum dimensions being 6 ft. and 8 ft. 6 in., approximately.

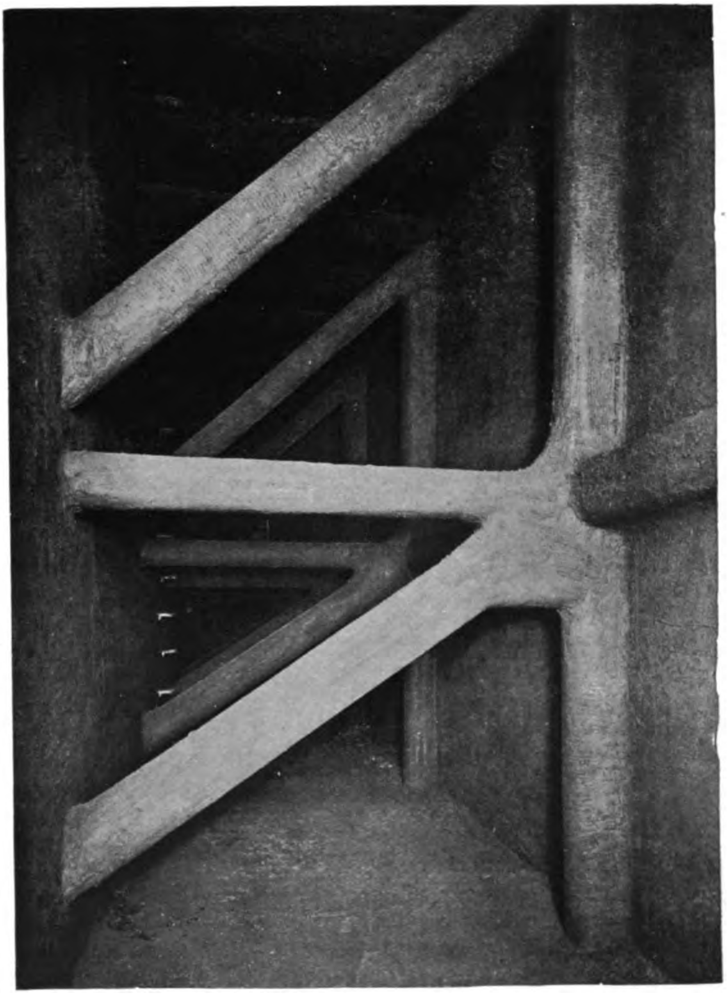


FIG 11. CHELSEA BATHS (INTERIOR VIEW).

The back wall is of exceptionally massive proportions because, in addition to the duty of holding up some 15 ft. of water, it has also to carry the main façade of the building. The front of the tank acts as a retaining wall for the earth beneath the roadway, and the upper surface of the roof takes the place of flags for the pavement of the footwalk.

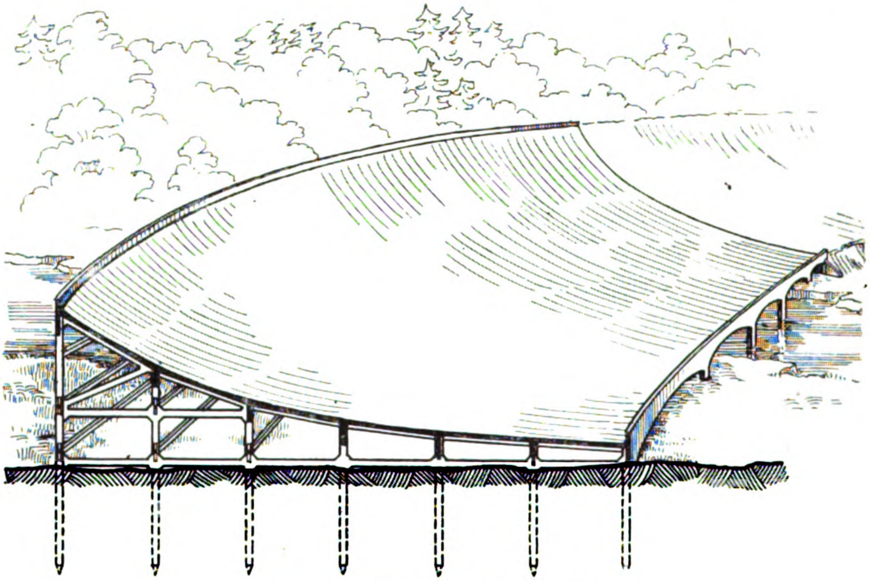
The lower drawing in *Fig.* 8 shows the arrangement of the reinforcement in the bottom and walls of the tank, and the upper drawing in the same figure shows the reinforcement in the roof.

Fig. 9 is a cross section, to enlarged scale, where the details of construction are more clearly shown. Besides being stiffened by counterforts at intervals of 10 ft. apart, the front wall of the tank is very adequately reinforced by horizontal and diagonal bracing, and the vertical joists in the counterforts are stiffened by angle bars distributing the load over the horizontal joists in the bottom slab of the tank as represented in *Fig.* 10. Generally speaking, the expanded metal sheets are applied between the members of the steel framework.

A good idea of the interior is given by *Fig.* 11, reproduced from a photograph taken after completion of the work.

THE BROOKLANDS MOTOR TRACK BRIDGE.

THE structure which we illustrate on this page forms part of the racing track which has been constructed near Weybridge railway station for the proprietors of the Brooklands Automobile Racecourse and Club. It was rendered necessary for carrying the track across the river Wey, and at the same time to provide a sufficient outlet for the passage of flood waters which come down the valley in considerable volume during periods of heavy rainfall. At one end of the bridge the outer edge of the track is banked up to the height of 40 ft. above the datum line, which is from 5 ft. to 8 ft. below normal ground level, and the inner edge is only 12 ft. above datum. At the other end of the bridge the outer edge is banked up to the height of 32 ft. above datum line, and the inner edge is about 10 ft. 6 in. above the same level.



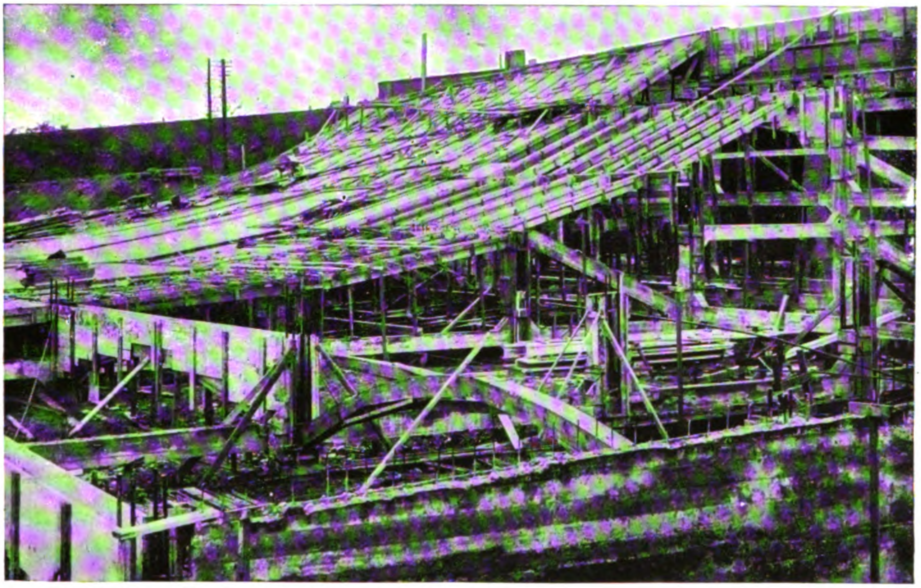
BROOKLANDS MOTOR TRACK BRIDGE.

Thus the outer side of the bridge slopes down to the extent of 8 ft., and the inner edge only about 1 ft. 6 in., the gradient being very gradual in the former case for three-fifths of the incline, and thence falling sharply for the remaining two-fifths, while in the latter case there are two approximately equal lengths with the gradients of 1 in 90 and 1 in 200.

From the foregoing measurements it will be seen that the bridge is of peculiarly distorted shape, a characteristic that is further pronounced by the fact that the plan of the structure exhibits two curves with the radii of 1,000 ft. and 2,000 ft. respectively.

The racing track has the uniform width of 100 ft., this being also the width of the bridge, which is nearly 200 ft. long. It will be at once apparent to our readers that the very unusual conditions here presented constituted a strong argument for the adoption of reinforced concrete construction, which, while combining the elastic strength of steelwork with the rigidity and durability of masonry, is far and away less expensive than either material, and free from the element of costly maintenance which is so great an objection to steel.

The foundations of the bridge (which has been designed on the Hennebique system) are constituted by some forty-two piles, most of which are 14 in. square, driven to predetermined depths and terminating just above surface level, where they were securely connected by horizontal bracing, which, together with the columns of the superstructure, were moulded monolithically with the heads of the piles, and all the reinforcing bars were carried from member to member so as to provide secure anchorage and to insure the proper distribution of stresses. Besides the horizontal bracing just above ground level and between the longer columns, adequate diagonals were moulded in a similar manner, the positions of some of these being shown in the sectional drawing.



The Brooklands Motor Track Bridge.
(In course of construction.)

The upper ends of all the columns are

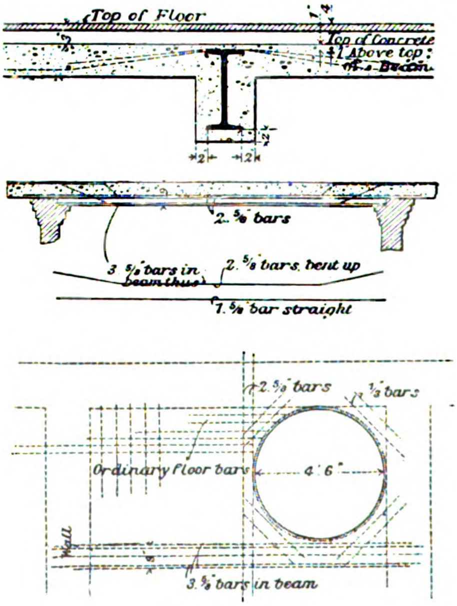
THE WALDORF HOTEL, GENERAL VIEW.

joined longitudinally and transversely by main beams set at varying angles with the horizontal, and having curved upper surfaces so as to provide for support of the conclave road decking. Between these members are secondary beams subdividing the deck slab into panels measuring about 17 ft. by 5 ft. each. The slab varies in thickness from 4½ in. to 6 in., according to position. The superelevation of the bridge being 26 ft. at one end and 15 ft. at the other end, and the curvature of the track increasing very rapidly towards the outer edge, it is evident that the trouble and expense of building the bridge in any material other than reinforced concrete would have been great.

At the upper end of the structure the spaces between the last row of piles, columns, bracing members and beams are filled in by panels of reinforced concrete for the purpose of holding up the earthen embankment, and, in order to prevent the material from flowing down towards the channel of the river, wing walls of suitable height and length have been built in continuation of the end retaining wall.

Similar treatment has been adopted at the lower end of the bridge, but the retaining and wing walls are not shown in our illustration, as the sectional elevation there included is taken on a line a few feet from the extremity.

This interesting example of reinforced concrete construction was executed by the Yorkshire Hennebique Contracting Co., Ltd., of Leeds, under the superintendence of Mr. L. G. Mouchel, the General Agent



FIGS. 1, 2 & 3.

for the system adopted. The work was completed within the short period of 3 months. The cement used was "J. B. White & Bros." Brand.

The structure was designed for the superload of 112 lb. per square foot, and the rolling load of two tons.

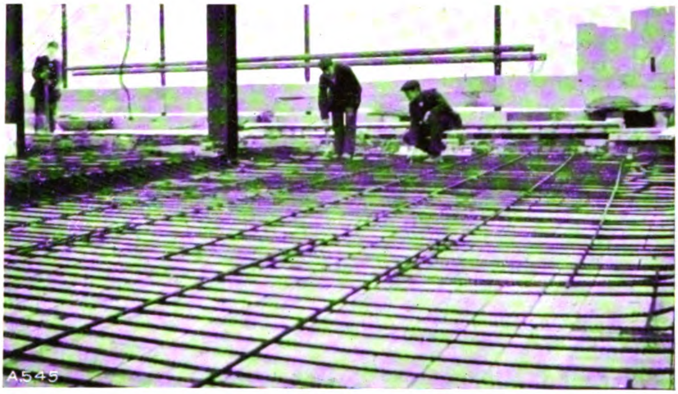


FIG. 4. "INDENTED" BARS BEING LAID OUT ON THE CENTERING.

REINFORCED CONCRETE FLOORS, AT THE WALDORF HOTEL.

IN our January number we published a profusely illustrated article on the Ritz Hotel, Piccadilly, dealing particularly with the steel framing and the concrete floors and roofs constructed on the Columbian system, and we now illustrate certain floor sections laid at the Waldorf Hotel, Aldwych, as indicating how reinforced concrete floors may be applied in conjunction with steel frame structures. The particular floors here illustrated were designed by the Patent Indented Steel Bar Co., and executed by the General Fireproofing Company of Glasgow, as sub-contractors to Messrs. Waring White, Ltd., who are erecting the building. Messrs. Marshall, McKenzie and Son are the architects for the hotel.

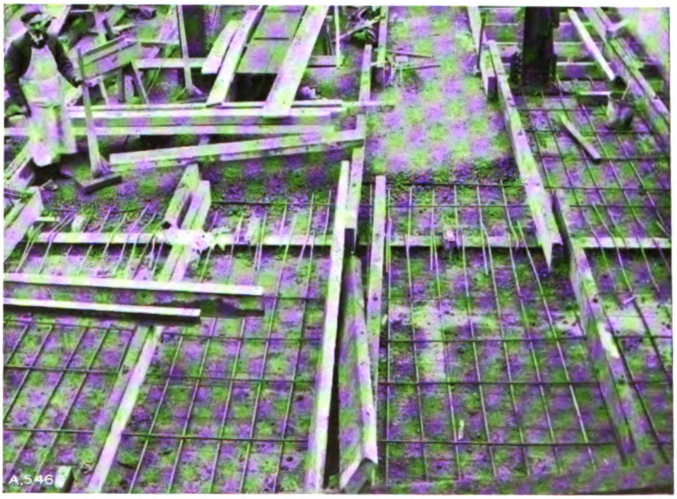


FIG. 5. FLOOR IN COURSE OF CONSTRUCTION.

It is not our purpose to here describe the steel frame construction of the hotel, for much that we have published in connection with our article on the Ritz Hotel would apply; but we give a general view of the building in course of construction. We would specially mention that, as at the Ritz Hotel, unfortunately, owing to our building regulations, unnecessarily thick outer walls have to be erected, regardless of the fact that these outer walls are nothing but screens for the steel-frame structure.

This hotel has a frontage of 190 ft., and extends back about 160 ft., being constructed on three sides of a square, on which the interior rooms face. It consists of eight stories, with a commodious basement containing two floors.

The building, as indicated, is being erected on the steel-skeleton principle, the floors, however, being of concrete reinforced by "indented bars" supported on steel girders, care being taken to see that all steel is covered by concrete to a depth of 1½ in., to act as a protection in case of fire.

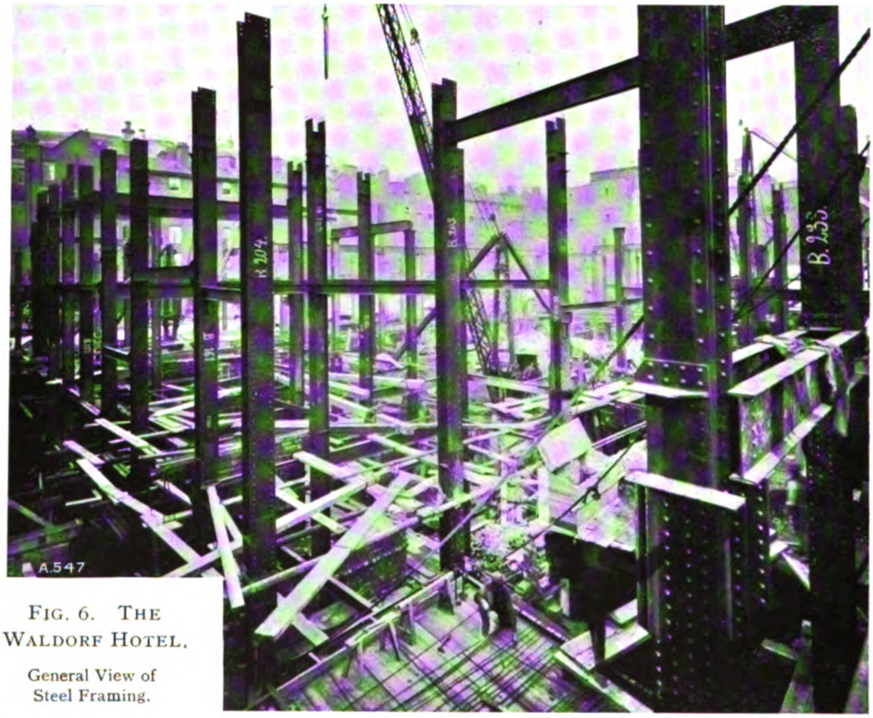


FIG. 6. THE WALDORF HOTEL.

General View of Steel Framing.

The general span of the floor slabs at the Waldorf Hotel varies from 8 ft. to 18 ft., but the same methods of proportioning and laying the slabs is followed throughout. The aggregate used was three parts crushed brick, two parts coke-breeze, two parts sand to one of cement, the whole being passed through a screen of 1 in. mesh.

Regarding the centering for the floors, it was supported in each panel by a couple of joists laid across the steel girders of the framework, two other joists being suspended from the first two by iron bolts which passed through the concrete, and were afterwards removed. The indented bars, after being hooked on to the girders, were then laid on the centering, and the loose end of the bar was left to project beyond the supporting girder to a length of about a quarter the span of the floor.

Three different loads were arranged for in the case of the Waldorf Hotel, and this, of course, necessitated a difference in the spans and spacing of the bars. The three loads were 225 lb. per sq. ft., 135 lb. per sq. ft., and 100 lb. per sq. ft.

The system adopted by the Indented Steel Bar Co. to ensure the bars being laid at the correct distance from the centering is to lay them on a round rod ½ in. in diameter, and to move this rod along between the bars and the centering as the concrete is put in. The bars are thus easily kept at the correct distance from the centering, and the proper spacing is arranged for by passing the bars through notches cut in a piece of wood. When the bars were laid and correctly spaced, cross-bars were inserted about 2 ft. apart, at right angles to the main reinforcing bars, but of the same size. The concrete was afterwards tipped on the rods, and rammed into position, the round rod before mentioned being moved on as each fresh batch of concrete was deposited.

Where openings occur in the floor slabs, special arrangements had to be made, and in some cases reinforced concrete beams had to be utilised in addition to special reinforcement.

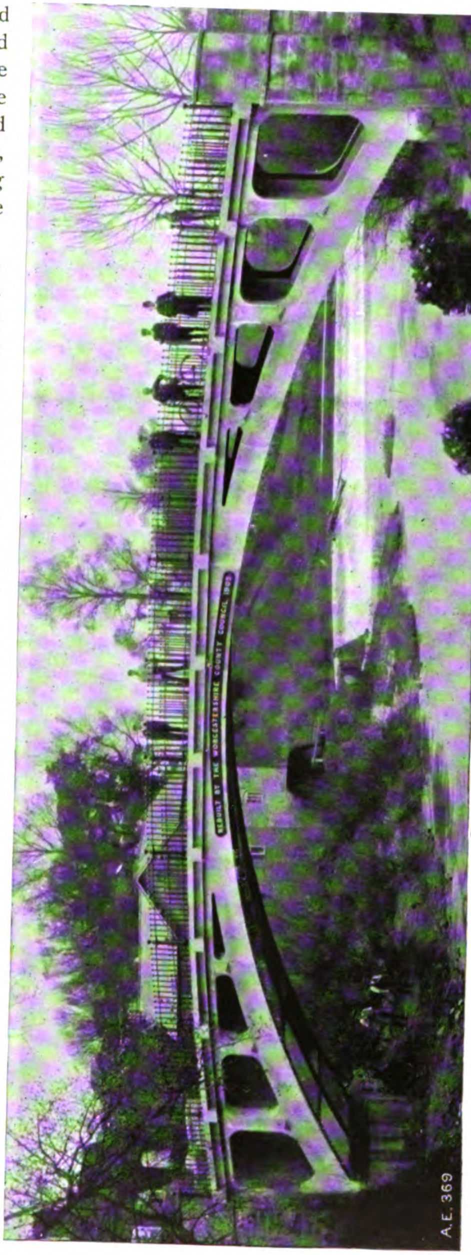
Referring to our illustrations, *Fig.* 1 is a section through a slab, showing the I beam supporting, while *Fig.* 2 shows the slab when resting on the supporting walls, and the bars alternately straight and bent up at the end.

Fig. 3 shows the special reinforcement which was necessary when openings occurred in the floor slabs, while *Fig.* 4 shows the bars and crossbars being placed in position ready for the concrete to be laid, as does also *Fig.* 5, while *Fig.* 6 gives a general view of the steel construction, with a small portion of a floor in the foreground.

We have been given particulars of a test carried out on the floor of a private dining room on the main floor, which was designed to carry a safe load of 2 cwt. per sq. ft. They are as follows:—

The panel was supported on main girders 10 ft. 10¼ in. centre to centre; the length of the panel being 26 ft. 11 in. The concrete slab was 5½ in. thick, and the reinforcement consisted of ½-in. "Indented bars" placed 5½ in. apart centre to centre, with four cross-bars at a spacing of about 2 ft. apart. The test was carried out by means of bags of cement placed in layers in the floor, the final load being 4 cwt. per sq. ft., or twice the calculated safe load. A factor of safety of four having been used in making the design, the ultimate test load was, therefore, half the calculated breaking load.

On the load being removed the permanent set due to the deflection of both the girders and concrete proved to be ½ in. The permanent set of the concrete slab was, therefore, somewhat less than this. The underslab was carefully examined when fully loaded, but no cracks or weakness could be discovered. Another panel, 12 ft. 1¾ in. wide and 23 ft. 6 in. long, proved to have no permanent deflection at all after testing to a load of 2 cwt. per sq. ft., the safe working load for which it was designed.



STAMFORD BRIDGE, WORCESTERSHIRE.

We are indebted for our illustrations to the Waring White Building Co., Ltd., and the Patent Indented Steel Bar Co., Ltd.

STAMFORD BRIDGE, WORCESTERSHIRE.

THE cast iron bridge over the River Teme has been replaced by a reinforced concrete arch.

This bridge, with the clear span of 98 ft. 6 in., is the most important reinforced concrete arch built in the United Kingdom. It was designed in accordance with the Hennebique system for the County Council of Worcestershire by Mr. W. Hugh Woodcock, M.Inst.C.E., of Westminster, and completed last year.

Reference to our illustration will show that the new bridge is a light structure comprising three arch ribs connected by lateral bracing formed by extension of transverse spandrel walls, which, together with the longitudinal pierced spandrel walls, afford intermediate support for the platform between the crown of the arch and the abutments.

The arch ribs, struck to the radius of 98 ft. 8 in., spring from a massive masonry abutment. They are connected at each end of the bridge by a strongly reinforced concrete slab, and between the bottom slab and the platform is a transverse wall binding together the whole construction, each end of which rests upon a pier projecting 2 ft. 6 in. beyond the face of the abutment. Without taking into account the thickness of the platform slab, the arch ribs are 1 ft. 2 in. thick at the crown, gradually increasing to 3 ft. thick at the springings. As a matter of fact, the effective thickness of each rib is 1 ft. 9 in. at the crown, increasing to 3 ft. 6 in. at the distance of 17 ft. 6 in. on either side of the centre. The width of the two outside ribs is 1 ft. 2 in., and that of the centre rib 1 ft. 8 in. To provide for tensile stresses that, under the influence of moving load, may be developed near either the upper or the under surface of the concrete, the arch ribs are reinforced by a double system of steel bars connected with overlapping radial stirrups for the resistance of shear at progressively increasing intervals, from 6 in. at the springings to about 15 in. at the crown, and are of such ample length as to permit the overlapped ends to be firmly anchored at the centre line of the rib.

Each of the two outer ribs contains two curved longitudinal bars and two similar bars near the upper surface. The middle rib, being wider, has three longitudinal bars at the bottom and top respectively. In the case of all three ribs, transverse bearing plates with split ends for anchorage are disposed at intervals across the lower series of bars, for the purpose of ensuring the uniform distribution of stress in the reinforcement.

The transverse spandrel walls are ten in number, and vary in depth according to their position along the axis of the bridge, but all of them have the uniform thickness of 6 in. They extend from side to side of the bridge, which is 13 ft. 6 in. wide between the outer faces of the arch ribs.

Built monolithic with them are the longitudinal spandrel walls, which are pierced, forming uprights 1 ft. 8 in. wide between the four openings. Both series of walls are reinforced in the manner commonly used for compression members with vertical and horizontal bars in the transverse walls, while the pilasters in the longitudinal walls have vertical bars and links as adopted for Hennebique columns and piles, and, in addition, diagonal rods passing into the arch ribs, and the longitudinal beams of the platform, and the upper part of the spandrels.

The bridge has the over-all width of 16 ft., providing for a roadway 13 ft. wide, on either side being a curb surmounted with iron railings. It was designed for a dead superload of 140 lb. per square foot, and a moving load of 65 tons extended on a length of 88 ft. The official tests were satisfactorily conducted in the presence of the engineers and others representing the Worcester County Council.

NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

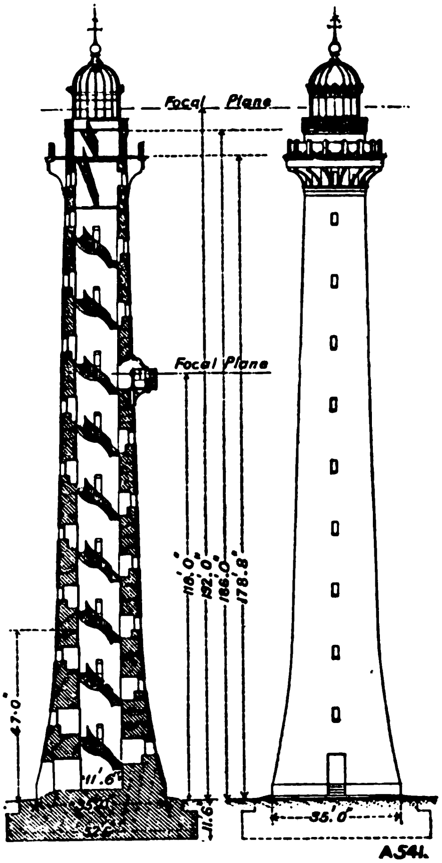
CONCRETE "TIMBERING" FOR COAL MINES.

In the mines of the Reading Coal Company at Shamokin, Pennsylvania, concrete has been tried—we presume with suitable reinforcement—as a substitute for the usual timber struts employed in colliery workings. Special plant has been laid down at the North Franklin colliery for the manufacture of concrete props, which will be supplied from this centre to all the other pits of the company. Some time ago the perishable character of timber, and the heavy cost of maintenance, induced the Reading Coal Company to undertake a careful investigation into methods and processes for the preservation of mine timbering, with no very satisfactory results, and we understand that reinforced concrete has now been recognised as a far better material for use in this direction. It is to be hoped that colliery proprietors in Great Britain will consent to lay aside the conservatism which characterises some of their methods, and take into serious consideration the desirability of following the good example set by the American company whose name is mentioned above.

We have previously indicated that a start has been made in this direction in some of the German coal mines.

REINFORCED CONCRETE LIGHT-HOUSES.

Lighthouse at La Coubre, France.

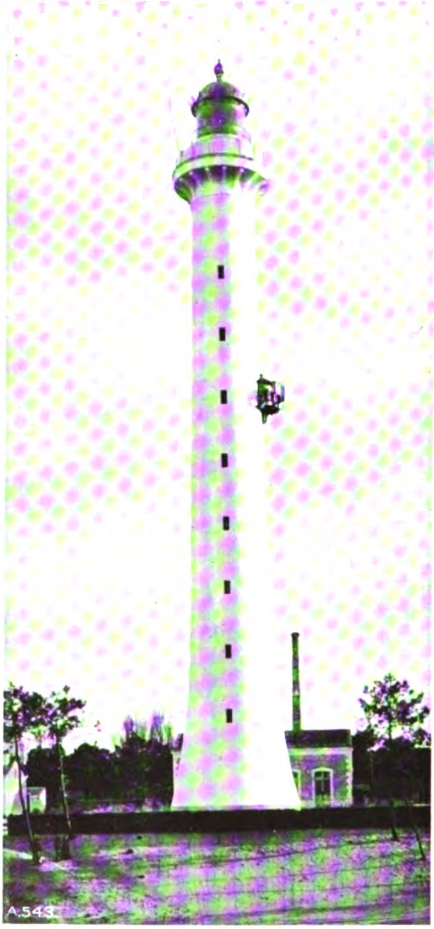


THE LA COUBRE LIGHTHOUSE.
Steel and Elevation.

Owing to the encroachment of the sea, the lighthouse that was situated upon the Point de la Coubre, on the north side of the mouth of the river Gironde, was found to be unsafe, and it was immediately resolved to erect a new lighthouse which would be out of reach of destructive influences. As it was necessary that the construction should be rapid, it was promptly decided to erect a reinforced concrete structure, and the time occupied in the work was the exceptionally short period of nine months.

The height of the tower to the focal plane is 192 ft. above sand level, or 203 ft. 6 in. above the foundations, and the ground is about 18 ft. above high water. The internal diameter of the shaft is 11 ft. 6 in. The thickness of the walls under the lantern gallery is 2 ft 3½ in. and the shaft has a uniform batter of 2·6 per cent. to within 47 ft. of the base, where the wall thickness is 5 ft. 10 in. The lantern gallery is 28 ft. in diameter, and the weight of the structure 149 lb. per cubic ft.

The floor of the service room under the lantern gallery is formed of armoured concrete 6 in. thick. The lantern floor is carried upon steel joists, and is also of armoured concrete. The shaft of the tower is armoured by a network of round iron bars, ·4 in. diameter, interlaced by a mesh of 8 in., and embedded in concrete 6 in. thick.



The La Coubre Lighthouse.

It was found possible to remove the forms after two days, and it is interesting to note that the cornices were formed in reinforced cement concrete.

As to the aggregate for the concrete, it was found that the sand to be obtained in the neighbourhood was not of very good quality, but in view of the need for rapid construction, it was used to mix with larger aggregate procured from the river Dordogne, as was also the sharp sand used for the face work. The balance of the aggregate was obtained from the surrounding dunes, and constituted about one third of the whole.

The foundations measure 52 ft. 6 in. diameter, and 11 ft. 6 in. deep, and are formed of solid concrete.

We are indebted to Monsieur Modelski, Chief Engineer of Coast Defences, (France), for our illustrations.

REINFORCED CONCRETE SEWERS.

Of the new uses for reinforced concrete, its application to sewers is certainly a most important one, and we are presenting characteristic illustrations of work in actual execution in France, the United States of America, and, last but not least, those being undertaken by the Columbian Fireproofing Co. at Acton.

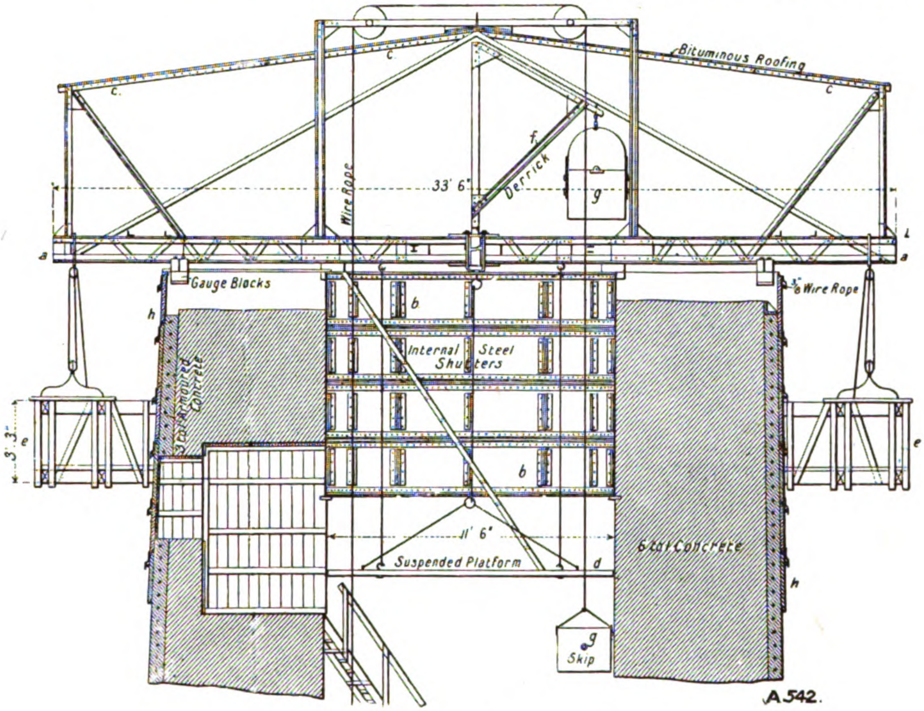
The French illustration is from the main outfall in Paris, of which Messrs. Chassin and Sons are the contractors and Messrs. Bechmann and Lanney the engineers. The diameter is 2 metres and the length about 2 kilometres.

The American example is one in which "Indented" bars are used, and is being constructed by Messrs. Hoffmann and Hogan for the Harlen Creek Public Sewer, St. Louis, U.S.A.

Regarding the Columbian Fireproofing Co.'s example for the Urban District Council of Acton, we give some additional particulars.

It is constructed on the "Bonna" system, and comprises a pipe of 4 ft. 6 in. diameter. As it is constructed near the surface of the road, it was deemed advisable to give it as much height as possible from the top of the sewer to the surface of the road without diminishing the sectional area. It is for this reason that the section selected is a semicircular crown with a segmental invert.

The Columbia 2 in. cruciform bars have been used throughout, and the thickness of the concrete on the crown is 6 in.



THE LA COUBRE LIGHTHOUSE.

(Showing construction).

The work is well deserving of a visit from borough surveyors, as an excellent example of its kind.

As to the construction of pipes on the "Bonna" system, we refer to a special report which was presented to the Norwich Corporation by their City Engineer.

REINFORCED CONCRETE PIPES IN FRANCE.

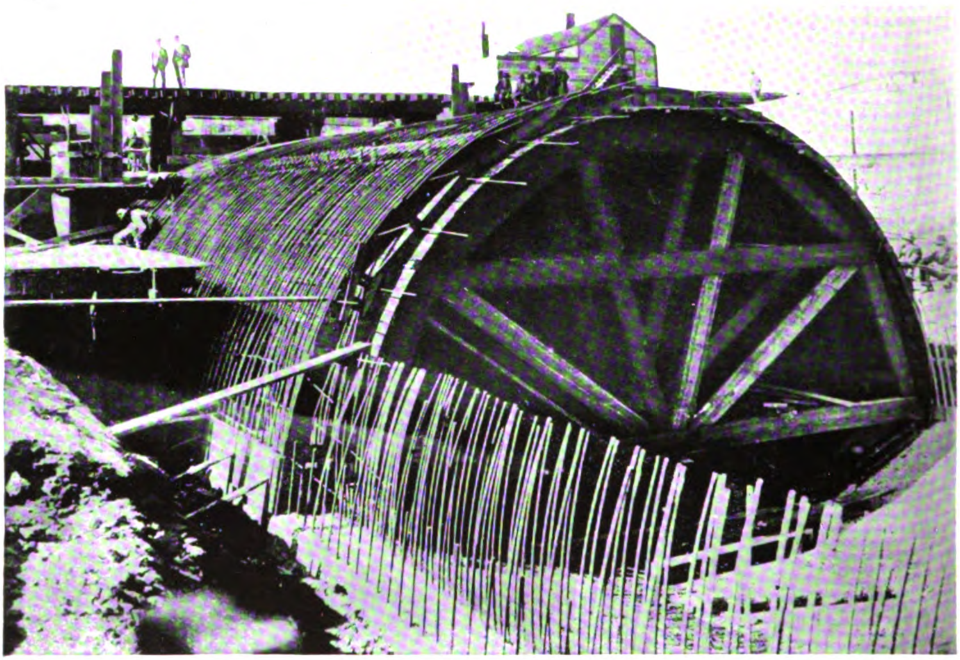
The following is from a report presented by Mr. Arthur E. Collins, M.Inst.C.E., Engineer to the City of Norwich, to the Sewerage Committee of that Corporation, arising from a visit of his to France, where he had been studying the question of reinforced concrete in connection with a pipe scheme for Norwich.

Mr. Collins's report is highly interesting reading, and not only describes how reinforced concrete pipes are constructed, but gives some valuable impressions.

The report might perhaps be read in conjunction with an article we published in our issue No. 3, Vol. 1., by Mr. R. H. Wyrill, M.Inst.C.E., Waterworks Engineer, Swansea, on reinforced concrete water mains.

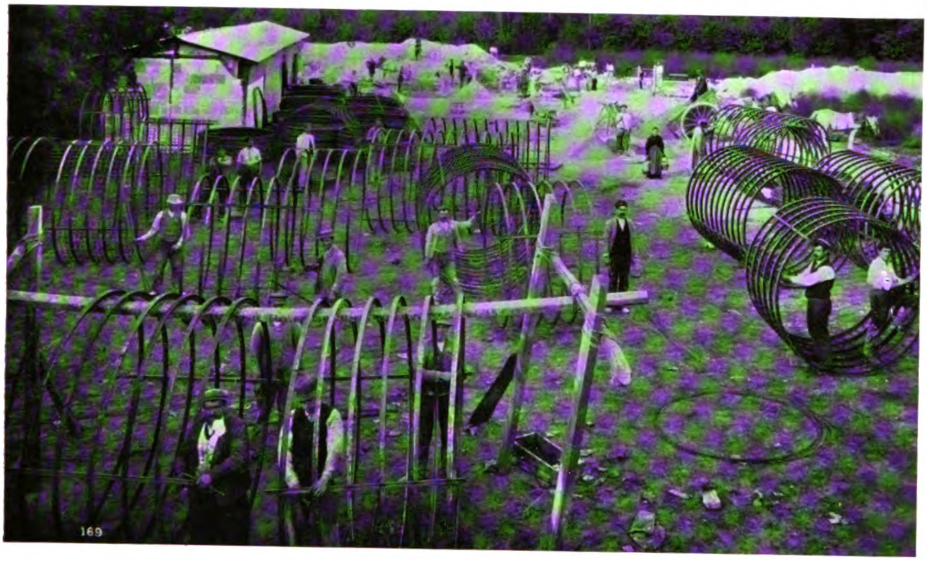
Pipes at Maisons-Alfort.

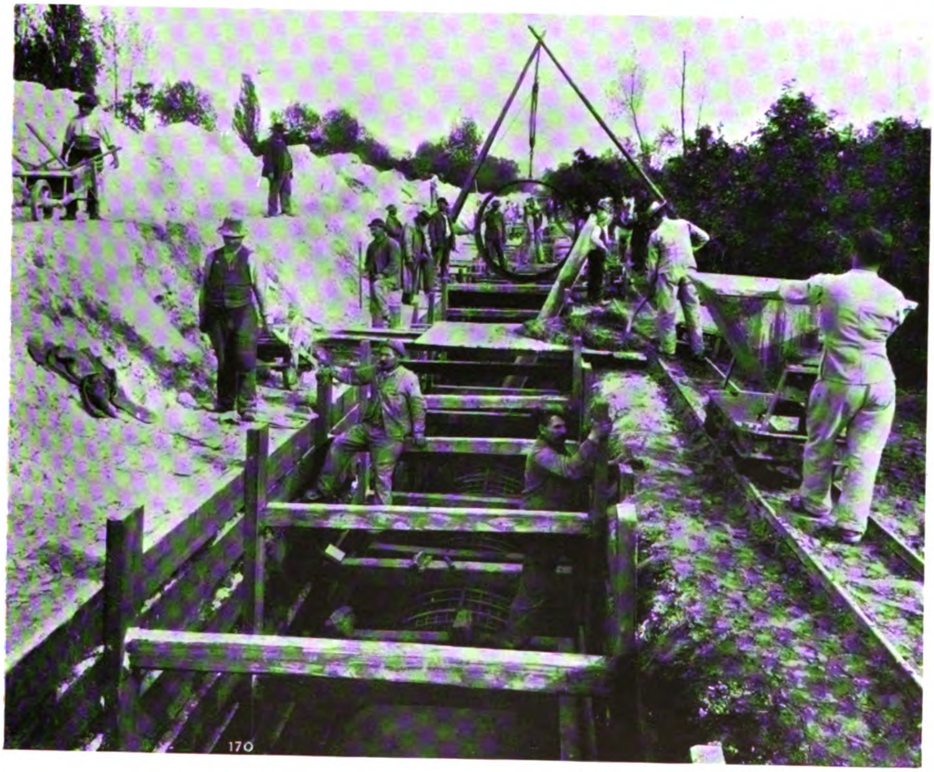
On March 29th I visited Maisons-Alfort in the Department of Seine, where a water main was being laid. The pipes were being constructed in a yard adjoining the road where they were to be laid. They had an internal diameter of 2 ft. 7 in., with thickness of walls of 2⅜ in. and length of 10 ft. The length of main was five miles. The internal pressure was 120 ft. head. At about mid-thickness of the pipe walls are complete cylinders of sheet steel; these cylinders are made at the spot, and are jointed by means of a special fusing apparatus, which fuses the two surfaces of steel into one at the junction. The apparatus in question consists of a mechanically operated blow-pipe, using a mixture of acetylene and oxygen. Before being fused together the edges of the sheets are turned up about ⅜ in., so as to give a convenient surface upon which the fusing apparatus may operate. This arrangement also gives a flexible or expansive joint, the value of which is apparent when the next process of manufacture is seen. This consists of placing within the steel tube a cage composed of steel of + section wound into a spiral with longitudinal rods at about 9 in. intervals; the longitudinal rods and the spiral are wired together at a sufficient number of intersections. The springiness of the steel tube enables it to be drawn over the internal cage, whilst at the same time it is in close adherence thereto. A similar cage, but of heavier section of steel, is drawn over the outside of the steel tube. The weight of the steel + section and the pitch of spiral depend on the diameter of the tube and the intended working pressure. The steel tube is of the same length as the pipe and is slightly flanged at each end; the internal cage is of almost the same length as the pipe; the external cage is slightly shorter than the pipe.



Reinforced Concrete Sewer with Indented Bar Reinforcement at St. Louis, U.S.A.

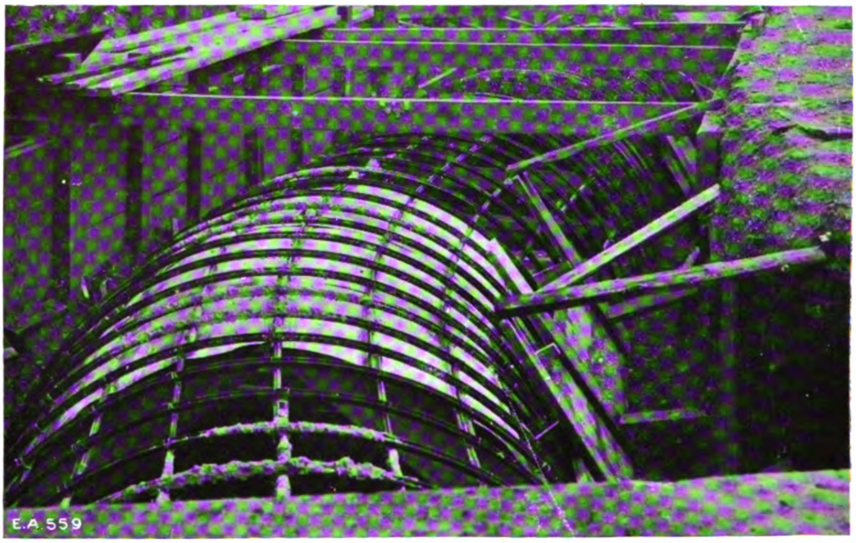
When the tube with its internal and

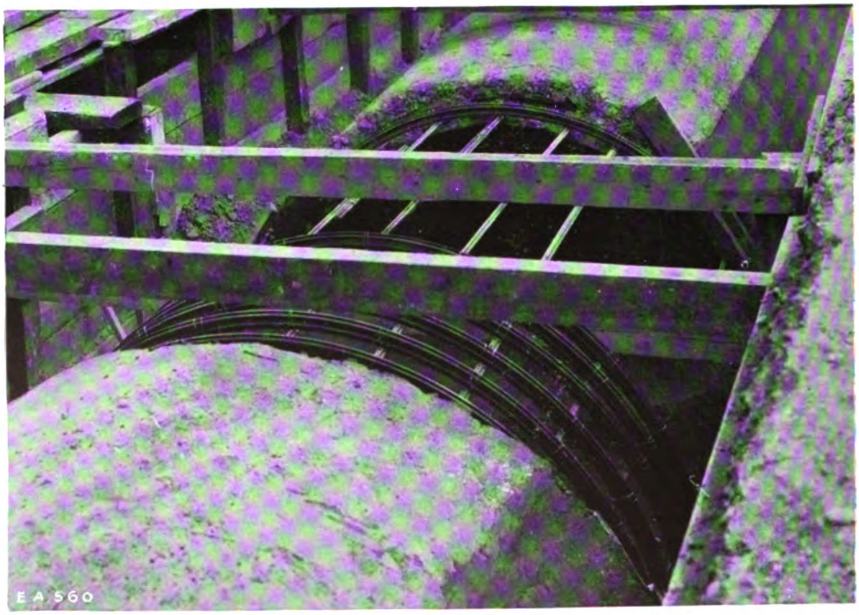




REINFORCED CONCRETE SEWER FOR THE PARIS MAIN OUTFALL ON THE CHASSIN SYSTEM.
(In course of construction.)

external cages has been assembled in the manner stated the assemblage is placed upright on a platen or table; a collapsible core of very ingenious construction is placed in position inside the assemblage, leaving sufficient space all round to be occupied by concrete; a cope in three parts is placed around the outside of the outer cage, leaving sufficient space for concrete there; concrete is then mixed by hand on a concrete mixing trough on an elevated platform running on rails, and provided with cranes and other conveniences. The trough is mounted to tip





Reinforced Concrete Sewer (on the Bonna System) at Acton, near London.
(In course of construction.)

to either end, and is 12 ft. by 4 ft. by 1 ft. 8 in. deep. A special mixing paddle is used somewhat similar to a small spade, but with slots in it. Four men mix the concrete dry, and six men mix it again wet. When thoroughly mixed so as to be in a practically liquid condition, by tilting the trough and opening a hatch in the lower end the concrete flows between the core and the interior of the assemblage, and between the cope and the exterior of the assemblage. During the pouring the cope is struck a series of blows with wooden mallets to assist in consolidation and in disentanglement of air.

I saw some pipes assembled, cored, coped, run and stripped, the cement in use being very quick setting.

I saw pipes which had properly matured being laid and jointed, the jointing being done on generally similar lines to the construction of the pipe.

In some cases where a slight amount of flexibility is required the first portion of the jointing is done with bitumen.

Pipes at Colombes.

The following day I visited the pumping station of Colombes, where I saw some large sewage pumping machinery. I followed the rising mains to Argenteuil in the district of Seine at Oise, being accompanied by the chief engineer of the pumping station. At this point I entered the galleries containing the rising mains, where I found a 6 ft. reinforced concrete "Bonna" pipe and a 6 ft. riveted steel pipe, both working at a pressure of 115 ft. head. These pipes were both constructed in 1894, the object of using the two sorts being to ascertain which gave the best results in work. The chief engineer informed me the result had been that it was necessary to overhaul and re-paint the steel pipe at varying periods from once a year to once in two years, and they often had to caulk rivets and joints to prevent weeps becoming serious leakages. At the time of my visit I noticed a large amount of work had recently been done to the steel main, and on enquiring the reason found that in consequence of the expansion of the steel the pipe had lifted itself off the brick piers supporting it for considerable lengths, causing concentrated crushing loads to come on the piers, which continued to receive the weight of the pipe, nècessitating the construction of new supporting piers throughout and the fixing of anchorage straps. Notwithstanding the pipe had been subject to thorough overhauling and the application of holding-down fittings, I noticed several weeps, but the steel pipe was in good working order and seemed likely to remain so for some years to come. The reinforced concrete pipe alongside, which had done exactly the same work for the same period, was drop-dry, and the chief engineer informed me it had never cost a penny for repairs since it was constructed.

Pipes at Montmartre.

On Tuesday one of the officials of the Paris Municipality met me at Avenue Trudaine, Montmartre, Paris, and took me into the galleries beneath the streets, where I followed a long length of 4 ft. 2 in. reinforced concrete pipe on the "Bonna" system working under a pressure of 150 ft. head. There were cast-iron branches connected to it, which were weeping at the joints, and rust was oozing out, but there was no such oozing or other defect noticeable in the case of the concrete pipe. The municipal officer informed me that nothing had ever been done to the reinforced concrete pipe. and, no defect having been found, there had been no occasion to enter it, but he was quite satisfied it was in perfect condition.

Pipes at Nimes.

The director of the Municipal Works at Nimes informed me that eleven years since a "Bonna" reinforced concrete main was laid in that town. The length was about two-thirds of a mile, and the internal pressure very nearly 300 ft. head. This pipe was so successful that several other pipes of the same description had been laid from time to time in Nimes. I was anxious in my enquiries to ascertain whether the steel reinforcement and tube deteriorated. The director informed me that he had had to connect a branch pipe to an old "Bonna" main, which necessitated cutting into the main. The result was most satisfactory, the adherence of the concrete with the steel tube internally and externally was thoroughly good, and the tube was in a state of thorough preservation, with no trace of deterioration. The steel reinforcement was in the same state of thorough preservation, and presented a blue appearance, without any trace of deterioration, whilst the concrete had become of such hardness it was difficult to break it with hammer and chisel; in fact, the pipes and their joints were perfect and absolutely tight. I saw a pipe which had been accidentally broken, and its appearance bore out the information given me by the director of Municipal Works at Nimes.

CORRESPONDENCE.

Under this heading we invite correspondence.

"CONTINENTAL METHODS OF CALCULATION" *

As put forward by Monsieur DE TEDESCO (Paris) and commented upon by "QUAESITOR."

REPLY BY M. DE TEDESCO.

SIR,—I fully agree with the opinion expressed by "Quaesitor" that it was not possible to cover so wide and complicated a subject as that involved by the title of my recent contribution within the narrow limits of a single article. In fact, it was my intention immediately after the publication of that historical introduction to demonstrate the manner in which rational methods can be treated, so as to furnish practical but rational formulæ, which are the only formulæ now accepted on the Continent.

Unfortunately the first article (that which has already been published in your valuable journal) could not appear for several months after it was written, and having been very busily engaged in writing an important scientific treatise, I was not in fit condition for the preparation of the second, and most interesting part, nor even for correction of the printer's errors and *fautes de plume*, which, I am sorry to say, occurred in the first part.

I give below, in regular sequence, the explanations asked for by "Quaesitor."

Yours truly,

Paris, May, 1907. N. DE TEDESCO.

Page 53.

Col. 1, line 12.—The author prefers to add: "Where 344 is not the unit compressive stress in the concrete, and 13,760 is not the unit compressive stress in the reinforcement, but both of them are only empirical constants." (See p. 54, col. 1, lines 18 to 21.)

Col. 1, line 30.—Everyone can see that "6·28 sq. in." is to be read.

Col. 1, line 31.—Much obliged. The author inadvertently read in the "weight" instead of the "area" column of his reference tables, thus obtaining $6 \times 1{\cdot}04 = 6{\cdot}24$, which represents pounds weight. We want, of course, 6 bars of $1\frac{3}{16}$ in. diameter.

Col. 2, line 13.—Perhaps. *De gustibus non est disputandum.*

Col. 2, line 23.—Of course.

Page 54.

Col. 1, line 5.—True.

Col. 1, lines 28, 31 and 32.—The author agrees with these additions if they will make matters clearer to English readers.

Col. 1, lines 38 to 43.—The two heights are not, of course, always equal, but are often practically the same. Computation of the true height, or length of the arm of leverage of the moment of resistance involves considerable expenditure of time. We must deduct from the total height H (*Fig.* 2) 1 in. or 2 in. for the concrete below the reinforcement, and from one-third to one-half of the thickness of the part in compression of the slab at the top of the beam.

Col. 1, lines 23 to 43.—As empirical formulæ are no longer officially recognised in France, their explanation is of little importance. However, the author may say that fifteen years ago he supposed that when reinforced with steel to the extent of 0·5 per cent. a slab might be regarded as homogeneous. Therefore he wrote, in metric units:—

$$M = \frac{d^2}{6} \times 30 = 5d^2$$

where M = bending moment in kilogram-metres; $\frac{d^2}{6} =$ the moment of inertia of a slab one metre wide by d centimetres deep; and 30 = permissible tensile or compressive stress in kilogrammes.

Converting to British units we get:—

$$M = \frac{5d^2 \times (2{\cdot}54)^2}{0{\cdot}304 \times 0{\cdot}138} = 768d^2$$

where M is expressed in foot-pounds per foot width, and d is expressed in inches,

or: $$d = \sqrt{\frac{M}{768}} = 0{\cdot}114\sqrt{M},$$

or with more safety: $d = 0{\cdot}12\sqrt{M}$

$$R = \frac{12d}{200} = 12 \times \frac{d}{200}$$

The factor 12 is employed to reduce feet to inches. The constant 1390 is readily understood if we remember that 16,680, or 12 × 1390, is the permissible tensile stress for reinforcement. Then 16680R is the tensile strength $= \frac{M}{h}$ (bending moment M in ft.-lb., lever arm h in feet),

or: $$\frac{16680R}{12} = 1390R = \frac{M}{h}$$

(bending moment M in ft.-lb., lever arm h in inches).

---

* See Vol. II. Nos. 1 and 2.

Page 55.

Figs. 3 and 4.—It must be admitted that the symbols, which are those given in the treatise previously mentioned, are not well chosen.

It would be better not to use them at all, and to substitute the following (see *Fig.* 4 *bis*):—

AB = maximum unit stress of the concrete in compression = R_c.

CD = maximum unit stress of the concrete in compression at the distance u' from AB = $R_c \frac{h-x-u'}{h-x}$.

RK = minimum unit stress of the concrete in compression in the slab

$$= R_c \frac{h-x-e}{h-x}.$$

EF = maximum unit stress of the concrete in tension = R_t.

GH = unit stress of the steel in tension =

$$R_c \frac{x-u}{h-x}.$$

The foregoing applies to remarks 1 to 4.

With regard to remark 5, the author may say that he thought it better in a historical review to employ the symbols which have been used by the various authors, in order to enable the reader to find the same symbols as in the corresponding treatises. Standardisation of terminology can only be realised in an original contribution.

In *Fig.* 4, l is correctly applied to indicate the total width of the slab in compression: the total width of the slab in tension should have been lettered l', but unfortunately the tick was left out by an oversight on the part of the draughtsman. It would have been more systematic to indicate the first by l' and the second by l, but the latter being very seldom used and the first always, it was not thought suitable to reverse the order of the symbols in question.

Page 56.

General Note.—With the above explanation this matter seems to be perfectly clear, and at all events clearer than the observation of "Quæsitor."

Col. 1, par (1).—The author quite realises the distinction here mentioned, and feels sure that his readers will extend to him the indulgence which may be hoped for by one who writes in a foreign language.

Col. 1, par (2).—"Compression slab" is not, of course, the proper term. The author means the wings of the slab, whose collective width = $l-a$, or taking a as the unit of width $\frac{l-a}{a}$. This is the same meaning the author gives to x, u u' e e', etc., the true values of which are $\frac{x}{h}$ $\frac{u}{h}$ $\frac{u'}{h}$ $\frac{e}{h}$ $\frac{e'}{h}$ and so on, but by taking h as the unit of height, the values can be expressed by the numerators alone.

See *Fig.* 4 *bis* for the trapezoid ABKR and its centre of gravity O.

At the option of the reader the meaning of λ can be either $l-a$, the absolute width of the wings of the compression slab; or $\frac{l-a}{a}$ their width relatively to a.

The printer's error is more important than Quæsitor supposes. Instead of "e" the numeral "2" should be substituted before h and x in the numerator of the second fraction of the last term, the correct version of the complete term being:—

$$\frac{e\lambda}{2} R_c \frac{2h-2x-e}{h-x}.$$

Col. 1, par (3).—Read "R'_c" in place of "Rc′" as printed. The words suggested may certainly be added after the word "then," if desired.

Col. 2, par (5).—See previous explanation as to the meaning of λ. By "breadth" the author means the collective width of the two tension wings, or $\lambda' = l'-a$, which is correct.

Col. 2, par (2).—The best thing is to refer again to *Fig.* 4 *bis.**

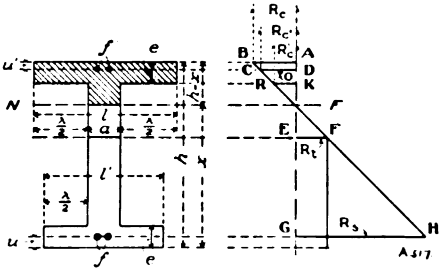


FIG. 4 *bis*.

Page 57.

Col. 1, lines 30 to 36.—True.

Col. 1, line 40, and Col. 2, line 2.—See previous explanation.

Col. 2, line 9.—There is here a manifest printer's error, and $\frac{l-a}{a}$ should be read instead of $\frac{l}{a}$.

---

* We have done so, but cannot find the letters ABA′B′ in either of the diagrams.—ED.

Unfortunately also, 16 was used in error for 60 (the width of the flange in Ex. 2 being $5\times12=60$ in.). Therefore all the succeeding calculations are wrong.

Further, this is not a case for employing the relative value of λ or $\frac{l-a}{a}$, but for using the absolute value $l-a$ because the bending moment has been expressed in absolute terms and not in relation to a. Consequently we have $\lambda=60-7=53$, instead of $\lambda=\frac{16-7}{7}=1{\cdot}29$, and all the succeeding equations and calculations must be altered as follows:—

$$1)\ \tfrac{7}{2}16-x)+\tfrac{3}{2}\times 53\frac{2\times16-2x-3}{16-x}$$

$$=15\times{\cdot}238\frac{x-2}{16-x}$$

$$x^2-78{\cdot}45x+916{\cdot}75=0$$

$$x=14{\cdot}3$$

$$h-x=16-14{\cdot}3=1{\cdot}7$$

$$h-x-e=1{\cdot}7-3{\cdot}=\ -1{\cdot}3$$

$$x-u=14{\cdot}3-2=12{\cdot}3$$

$$(2)\ \frac{M}{R_c}=\tfrac{7}{3}+(1{\cdot}7)^2+\frac{53\times3}{3}\left(\frac{3^2}{1{\cdot}7}-3\times1{\cdot}3\right)$$

$$+15\times{\cdot}238\frac{(12{\cdot}3)^2}{1{\cdot}7}$$

$$\frac{M}{R_c}=2{\cdot}89+74{\cdot}20+317{\cdot}71=394{\cdot}80$$

$$Rc=\frac{50{,}000}{304{\cdot}80}=126{\cdot}6 \text{ lb. per sq. in.}$$

$$R_s=126{\cdot}6\times15\times\frac{12{\cdot}3}{1{\cdot}7}=13{,}740 \text{ lb. per sq. in.}$$

Finally the author takes the opportunity of saying that in view of more recent and much more handy methods of calculation the above equations have only historic interest.

"REINFORCED BRICKWORK TANKS."

As put forward by MR. JAMES STUART, M.Inst., C.E., New Zealand.†

SIR,- In your March number there is an article by Mr. James Stewart describing some reinforced brickwork tanks designed and constructed by him in New Zealand. If I understand the writer correctly, his system consists in laying a calculated number of wire spirals in the horizontal joints of the tank wall, and it would appear, therefore, that the construction of the brickwork must be a costly and laborious process, as the bricklayers can only lay one or two courses at a time, and must then wait until the spirals have been laid before they can proceed with their work. It will also be observed that this system entails most careful supervision to ensure that the requisite amount of reinforcement has been put in, and an inspecting officer has no means of ascertaining whether the work has been properly carried out. The largest tank constructed on this system is given as one for 20,000 gallons.

Later on in his article the writer takes occasion to criticise the system of reinforcing brickwork tanks designed by myself, and does not consider it sufficiently secure. It may, therefore, interest you to know that the tanks constructed on my system some years ago are entirely satisfactory, and that I have recently constructed four 40,000 gallon tanks at a cost of less than £100 each, no difficulty being experienced in making them watertight, although the walls are only 9 in. thick, and only a poor class of bricks could be obtained. I am expecting before long to construct some tanks of 50,000 gallons capacity, and anticipate no difficulties, especially as it has now been found quite easy to heat and hook up the ends of each ring without the use of wire binding, as described in Mr. Marsh's book. As in my system the brickwork can be carried on continuously until completion, and as the whole of the reinforcement is visible for inspection until finally plastered over, it is not open to either of the objections to Mr. Stewart's method pointed out above.—Yours truly,

E. STOKES-ROBERTS
(Major, R.E.).

Jubblepore, India, April 19th, 1907.

---

† See Vol. II, No. 2.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume II. No. 4. SEPTEMBER, 1907.

EDITORIAL NOTES.

REINFORCED CONCRETE AND THE LOCAL GOVERNMENT BOARD.

THE antagonistic attitude taken up by the Local Government Board in respect to the period for loans on works constructed in reinforced concrete is becoming a very serious matter, as far as our municipalities and local authorities are concerned. Numerous municipalities are desirous of carrying out their structural work as economically as possible, but they cannot afford to incur indebtedness that has to be repaid in exceptionally short periods of time. The short loan periods practically compel them to adopt older and more expensive methods of construction to the detriment of sound construction and to the disadvantage of the ratepayer.

The Local Government Board appears to be only granting approximately 15 years' loan periods for work in reinforced concrete, as compared with 30 years for stone and brick buildings, but although reinforced concrete is as a rule materially cheaper than either stonework or brickwork, it is not as yet so much cheaper (*i.e.*, 40 to 50 per cent.) as to make the loan period a matter of little moment.

In one recent case that has come to our knowledge—namely, that of the reinforced concrete pipe work at Norwich—we observe the anomalous position of the reinforced concrete mains being only allowed the 15-year period, whilst the buildings which are of brickwork with timber principles and tiled roofs have the 30 years' period granted them, and similarly the cast-iron portions of the mains.

Norwich has, fortunately, been able to afford the shorter period of repayment, and is thus able to benefit the ratepayers by providing them with cheaper pipes than they would have otherwise have had to pay for; but it cannot be said that municipalities as a rule are sufficiently prosperous to be able to do this.

We are, of course, fully aware that if bad workmanship is provided or if incompetent designs are used, the probability of failure is greater during the building operations in reinforced concrete than in ordinary brick and stone, but given once the complete building, properly set, the reverse may be taken as a fact, as the monolithic character of reinforced concrete structures and the nature of the material used, all go in the direction of improvement rather than deterioration as time passes.

We are fully aware, also, that the Local Government Board must protect itself in every way, but surely the protection should take more the form of according expert attention to the designs submitted, and perhaps laying down some rules as to supervision, inspection and testing than by taking such steps on the question of loan periods as in our opinion now practically compel many municipalities to build more expensive structures than they would wish.

We feel sure that further study of the subject by the Local Government Board must result in reinforced concrete being dealt with equitably—*i.e.*, on the same lines, at least, as the more ordinary and less substantial forms of construction. The Local Government Board must surely meet modern requirements in building construction and avoid encouragement of waste.

QUESTIONS IN PARLIAMENT.

Questions in Parliament in the matter of reinforced concrete have shown us of late that whilst the Local Government Board is on the one hand depreciating the value of this form of construction, other Government Departments are using it. Not only are the new General Post Office buildings and other post offices being constructed in reinforced concrete, but the War Office and Admiralty have utilised this form of construction, and, as a contemporary remarks, it is really somewhat amusing that while one Government Department considers reinforced concrete good enough for a post office building of practically 10 *million* cubic feet, a municipality should be told that 10 *thousand* cubic feet of reinforced concrete building was practically not good enough to grant more than a 15 years' loan on. A little more unition among the Government Departments on purely technical questions might be an advantage to both taxpayers and ratepayers.

In Parliament, for instance, we are pleased to record that Mr. Harcourt, Chief Commissioner of Works, in reply to a question by Mr. Whitehead, M.P., stated that he was "advised that the permanency and duration of such structures is likely to be at least as great as those of bricks and mortar." He also informed the House of Commons that the saving by employing reinforced concrete in lieu of ordinary materials was 20 per cent.

Again, Mr. Haldane, the Secretary of State for War, in reply to a public question in the House of Commons as to reinforced concrete construction undertaken by the War Office, stated "that this material has been employed to a considerable extent both at Woolwich Dockyard and at Woolwich Arsenal . . . that no accidents have been experienced during execution or since occupation . . . and that it (reinforced concrete) is found to be economical and satisfactory."

We should be pleased if some statements were also obtainable from the Admiralty as to the use of reinforced concrete on naval works, and trust that some member will also take this matter up.

POSSIBILITY OF REMEDY.

As to the possibility of remedy, as far as we can observe, the technical advisers to the various municipalities, either city engineers or city architects, might do well to jointly put the matter before the Local Government Board. Experience should be quoted of municipal and other works carried out in this country, notably those works carried out in connection with our great Harbour Boards and Railway companies. It might also be of assistance to point to foreign examples, and to give instances of works that are more than 15 years old.

The best compromise on the matter, pending the final solution, should be, however, one which we believe has already been attempted by the Local Government Board in the case of a bridge—namely, that of stating that the Board will only determine the additional period of loan beyond that of 15 years after completion of the structure. As the Local Government Board is stated to particularly fear accident during construction, this cause for misgivings at least, would have been set aside before final loan period came under consideration.

We suggest the above compromise to be the obvious policy prior to definitely allowing municipalities to build in reinforced concrete on equitable terms, which all local authorities will be the more desirous to do in the next few years, after it becomes generally known that the Imperial Government has in three of its departments set the example of carrying out works economically in this material.

LEARNED ASSOCIATIONS AND REINFORCED CONCRETE.

It affords us much pleasure to point to the meeting of the British Association as again indicating the increasing interest in reinforced concrete, for at this notable gathering there were two papers on the subject, one presented by Mr. Noble Twelvetrees, M.Inst.C.E., entitled, "Some new uses for reinforced concrete," and the other by Mr. De Vesian, M.Inst.C.E., on more general subjects.

As at the Engineering Conference earlier in the summer, where reinforced concrete was to the fore, we would remark on the tactful manner in which Mr. De Vesian dealt with his subject, although necessarily prejudiced in favour of the Hennebique system, with which he is primarily associated. But though we are in full agreement with much that he has put forward, on some points we are entirely at variance—*i.e.*, in respect to his argument as to the impossibility of drawing up rules for reinforced concrete construction generally, his views as to suitable aggregates and those depreciating the value of bars that afford a mechanical bond.

In particular we consider that rules are possible and advantageous, and we should like to see some model rules prepared for the adoption of municipalities on lines similar to the model by-laws for general building construction.

Regarding Mr. Twelvetrees' paper, we consider it most suitable that the subject of New Uses should be ventilated before such an important gathering, and his examples of the application of reinforced concrete for railway work in particular, should claim the attention of all railway, dock and harbour engineers both at home and in our Colonies.

THE PACKAGE OF PORTLAND CEMENT.

We deal with the revised Standard Specification elsewhere; we would, however, like to call special attention at this place to one paragraph in the specification which reads as follows:—

> "The cement shall be delivered in packages marked with the manufacturer's name."

In the Report of the Reinforced Concrete Committee, dealt with in the previous issue, there occurred the following paragraph:—

> "The cement should be delivered to the works in bags or barrels bearing the maker's name and the weight of the cement contained."

It is both interesting and remarkable that two bodies working independently—namely, the Reinforced Concrete Committee and the Cement Standard Committee—should arrive at an identical recommendation, and it speaks volumes for the importance of that recommendation that it should have been arrived at so unanimously.

With the increasing use of Portland cement the importance of obtaining what is specified is vital.

The danger of faked or fictitious Portland cement is increasingly great. Tests alone will not always safeguard the consumer, for many a delivery is made by unscrupulous merchants on the assumption that it will not be tested, for it is practically impossible to test all deliveries, especially to smaller jobs. In such cases the name of a reputable manufacturer on the package is a safeguard of real value which we are glad to see has now been realised by such competent authorities as those above mentioned.

The Revised British Standard Specification for Portland Cement

The Revision of the British Standard Specification for Portland Cement, must naturally be of interest to all connected with Reinforced Concrete, and we are thus presenting an article on the subject.

Of all the safeguards indicated in the original and revised specification we cannot, however, conceive—from the consumer's point of view, and especially as far as the small user is concerned—any more useful recommendation than the Committee's suggestion that cement should only be received at the works in the maker's bags or barrels.

There has been far too much substitution of spurious Portland Cement under fictitious labels in this country in the past, and now that the epoch of reinforced concrete has commenced, nothing can be a greater safeguard, in addition to the testing of samples, than the delivery of the cement on to the works in its properly labelled packages.—ED.

Probably no one welcomed the formation of the Engineering Standards Committee in the year 1903 more than the British cement manufacturer, who for years had been labouring under the no-inconsiderable difficulties of having to produce his cement to a multiplicity of specifications to suit the constantly varying ideas and requirements, and even fads, of engineers, not only in this country, but in the Colonies and abroad. Almost every engineer and architect had his own views as to fineness of grinding, strength, and chemical composition, for which in many cases he could give no adequate reason; while a variety of tests were in vogue, many of which were of small practical value in determining the true quality of the product. These fads and fancies undoubtedly put the manufacturer to very considerable inconvenience in preparing cement for the market, and often resulted in serious friction between seller and buyer, as beyond all question parcels of cement were frequently rejected by engineers of good repute either at the works, or, what was worse from the manufacturer's point of view, after delivery, which were of first-rate quality and quite equal to the standards set up by other equally eminent engineers.

It has been said that special requirements necessitate special specifications. Although this is undoubtedly true so far as the setting properties of the required cement are concerned, there is no reason why a specification should not be devised acceptable alike to the manufacturer and to the professional man, which would procure the manufacture of a cement of unimpeachable quality and suitable for every purpose. Such specifications have been satisfactorily in use abroad for many years past, and the success which attended the introduction of the British Standard Specification some three years ago is sufficient evidence that a uniform standard specification filled a much-needed want in this country. It was immediately adopted by Government Departments, Municipal Authorities, Harbour and Water Boards, Railway Companies, and indeed, almost all the principal users of

Portland cement throughout the country, and also very largely in the British Colonies and Dependencies. Its effect upon the product itself has been great, and a considerable percentage of the cement now manufactured in this country conforms to the high standard laid down in the specification, largely due to the finer grinding of the raw material and of the finished product, an expensive matter, which in many cases doubtless has necessitated the provision of new plant, and to more efficient burning and selection of clinker, which also entails additional expenditure.

The British Standard Specification, which has again come prominently before the public on the recent issue of a revised edition, has naturally not escaped criticism, particularly regarding the Le Chatelier boiling test for soundness, which, on its introduction, some authorities, including Mr. D. B. Butler, considered unnecessarily severe, and likely to result in frequent condemnation of good sound cement. The Committee, however, have retained this test in the revised specification, and have even made it somewhat more stringent. The Committee is composed of eminent representatives of the technical professions as well as of manufacturers and of important users, and it may therefore be assumed that they were satisfied that experience extending over a period of three years had fully justified its adoption, and that the fears expressed by certain experts as to the commercial value of this test have not been realised in actual practice. The Faija test for soundness, which Mr. Butler prefers, is a useful one, and one that is still largely employed in the laboratories of the leading works in this country, but the balance of opinion appears to be decidedly in favour of the one adopted by the Committee. In the original specification the limit of expansion after twenty-four hours' aeration was 12 mm., and after seven days, 6 mm.; it has now been reduced to 10 mm. and 5 mm. respectively.

With regard to fineness, no user is likely to quarrel over the reduction in the residue on the 180-mesh sieve, which is now not to exceed 18 per cent. as against 22½ per cent. in the original specification, the residue at 3 per cent. on the 76-mesh sieve remaining unaltered. Fineness of grinding is of prime importance in the production of a high grade cement, and long since our leading manufacturers recognised the commercial advantages to be gained from a pre-eminence in this respect. There exist factories in this country producing cement as a matter of everyday practice, with a residue of 5 to 6 per cent. on the 180-mesh sieve, and we doubt if this record is equalled by any concern outside the United Kingdom. The reduction of cement to this exceeding fineness is obviously an expensive operation for reasons which will appeal to anyone with a knowledge of grinding costs, and it is therefore all the more pleasing that we have in our own country enterprising firms who are not merely content to conform to the high standard required of them, but are determined to be well in advance of it.

The requirements as to tensile strength of neat cement remain without change—namely, 400 lb. per sq. in. at seven days from gauging and 500 lb. per sq. in. at twenty-eight days, but the proportion for the increase from seven to twenty-eight days has been reduced. An increase of 10 per cent. is now required when the seven days' test falls between 550 lb. to 600 lb., and 5 per cent. when the seven days' test is 600 lb. or upwards. The specified tensile strength of sand briquettes has been increased from 120 lb. at seven days from gauging, and 225 lb. at twenty-eight days to 150 lb. and 250 lb. respectively, the percentage of increase from seven to twenty-eight days remaining as before at 20 per cent.

It is a matter of regret that there should be in this revised specification some points of considerable importance which are lacking in that definite and clear description which might have been expected of the Committee, particularly in view of the difficulties which we understand have arisen from the same cause under the old specification, not only as between the manufacturer and the expert, but between the experts themselves. For instance, the quantity of water to be used in gauging is still vaguely defined as "being appropriate to the quality of the cement, and shall be so proportioned that when the cement is gauged it shall form a smooth easily-worked paste that will leave the trowel cleanly in a compact mass." There may be some difficulty in fixing a definite percentage of water which would be generally acceptable, for this depends upon such considerations as the age of the cement, the fineness to which it is ground, and the temperature and dryness of the air, but the description of "compact mass" is capable of being construed very differently by different individuals, and we can well understand that this absence of clearness of expression may result in friction in the future, as we are informed it certainly has in the past.

Then, on the controversial point as to when the cement is really set, the Committee again make use of the following words, which appeared in the original edition:—"The cement shall be considered as finally 'set' when a 'needle' . . . . fails to make an impression when its point is applied gently to the surface." The question will still arise as to what is an impression. It it well known in the trade that pats made of cement of unquestionable quality, particularly that made by the Rotary Kiln process, will show a *slight* impression some hours after the actual final set has taken place, and it is therefore open to an expert reading the above words literally to reject the cement offered on the ground of its being too slow-setting. It is to be hoped that the Committee will give their serious attention to these important points with a view to more definite description when the time comes for a further revision.

We would venture to make a further suggestion to the Committee—namely, that in any future edition they may publish, the metrical equivalents should be given of the British terms which are used. The British manufacturer, fortunately for himself and for the country at large, carries on a considerable foreign business, and in many markets—for instance, in South America—we think the carrying out of our suggestion would be welcomed by both buyer and seller, and would tend, we feel sure, to a wider adoption of the specification itself outside the United Kingdom.

With regard to setting time, the specification recommends three distinct grades—namely, "quick," "medium," and "slow"; and it is understood that this classification has worked well since it was introduced in 1904. "Quick" is defined as not less than ten minutes nor more than thirty minutes; "medium" as not less than half an hour nor more than two hours; and "slow" as not less than two hours nor more than seven hours, as against five hours in the original edition. In the official *communiqué* of the Engineering Standards Committee, it is stated that the Sectional Committee have had under their consideration for some time past the question of making some stipulation as to initial setting time, and experiments have been and are being carried out with a view to the inclusion of a clause dealing with this point.

The permissible addition of calcium sulphate (gypsum) at 2 per cent. remains unaltered, but the percentage of sulphuric anhydride has been raised from 2·5 per cent. to 2·75 per cent. We are inclined to doubt whether this will meet with unqualified approval in view of the prejudice which exists among many of our leading engineers regarding the use of gypsum. The percentage of magnesia at 3 per cent. and the insoluble residue at not exceeding 1·5 per cent. remain unchanged. An example is given showing the method of calculating in chemical equivalents the proportion of lime to silica and alumina. The design of the standard needle has been slightly modified with a view to diminishing the risk of injury and to allow of the ready replacement of the point if damaged, but no alteration in the essential features has been made.

One other point of importance may be mentioned, and that is the stipulation which appears in the revision that the cement shall be delivered in packages marked with the manufacturer's name. It is not without interest to observe that the report of the Joint Committee on reinforced concrete, adopted by the Royal Institute of British Architects on May 27th last, and published *in extenso* in the last issue of this Journal, advocates a similar requirement as to cement delivered for reinforced concrete work. That these two important bodies, acting independently of each other, should be in agreement in this respect is not without significance. It now remains for the consumer, for whose protection this stipulation has been adopted, to see that the requirement is rigidly conformed to.

The Committee are, we understand, making certain investigations, the desirability of which has been brought to their notice, but they decided not to hold back the issue of the present revision pending the completion of these experiments, which are likely to occupy some considerable time. A prospect is thus held out of a still further revision at no distant date. Finality in the matter of a standard specification for cement, like most other things in this world, is not likely to be reached yet awhile, and in the march of progress the labours of the Committee may be in requisition for a long time to come. Meanwhile, the thanks of that large section of the community which is interested in constructional work in this country are due to those gentlemen who have gratuitously given their services in a public cause, and have produced a standard specification which, although possibly still open to some criticism, is of undoubted value, and much in advance of anything that preceded it.

The Historical Evolution of Reinforced Concrete in Austria.

By **DR. LUDWIG HESS**, Brünn.

Although we generally look upon France and Germany as the pioneer countries of reinforced concrete, Austria has by no means neglected the introduction for public works and industrial undertakings, and thus claims attention from a historical point of view.

As in Germany, the development of reinforced concrete in Austria was originally in no small degree subject to the system put forward by Monier and his German collaborators, but, as in Germany, "systems" and "patents" do not play quite the same role in Austria to-day as is the case in several other countries, and the designing of reinforced concrete structures may be considered a matter of ordinary practice in the offices of the leading civil engineers, be they in public employment or in private practice.

That this fortunate state of affairs should exist is, in the main, due to the eminent Austrian professors of technology, who took up the subject in its early days of the eighties and nineties, as also to the writings and successful propaganda of Dr. Von Emperger, the eminent editor of our contemporary, "Beton und Eisen."—ED.

AUSTRIA has the proud distinction of being one of the countries in which the practical application of reinforced concrete was originated. And not only that, but the first scientific theories of the new mode of construction, on the basis of which the present methods were developed, arose in Austria.

Soon after Monier had attained his first successes in France, attempts were made to secure his various patents for Austria. So early as 1880 Mr. Rudolph Schuster concluded an agreement with Monier, and in the succeeding years carried out a series of works on the new system. Amongst them, according to a publication by R. Schuster and W. Wenzel (apparently published in 1887), were the following: 28 reservoirs and vats for the Vienna Reindorfer Spirit Distillery; fire-resisting doors for the Wertheim Safe makers; several reservoirs with dividing walls for a distillery at Lundenburg; bleaching tanks for the Paper Works at Franzenstal; and 550 sq. metres (642 sq. yds.) of vaulted flooring, and several tanks, for the Neubruck Paper Works.

The ground was so far prepared, when the general representative of the Monier system in Germany, Mr. G. A. Wayss, joined with Mr. Schuster to form an Austro-German company, Wayss directing the German, and Schuster the Austrian branch. The Austro-German company only lasted until 1893, when it was converted into the firm of Wayss and Co., under which name it still exists.

To the same time, 1887, belongs the first important Austrian pamphlet on reinforced concrete, entitled "The Monier System," which was published in Vienna. In this appeared the first description of an official loading test carried to destruction. This was a trial section of the Vienna-Neustadt aqueduct. The section was 3 metres (9 ft. 9 in.) wide, 4·5 metres (14 ft. 7 in.) high, and 1 metre (3 ft. 3 in.) long. The thickness of the arch was 130 mm. (5 in.) throughout. The reinforcement consisted of an inner network of 7 turns of 15 mm. (0·6 in.) and 10 turns of 10 mm. (0·4 in.) diam., linked together by winding with 10 mm. wire. Besides this there was a middle network of 12 mm. turns and 10 mm. binding, and an outer one of 10 mm.

wire. All of these were held in position by means of winding with 6 mm. (0·25 in.) wire. The roof had a further reinforcement of 5 wires of 10 mm. Rupture occurred at a load of 151,100 kg. (332,000 lb.), the maximum deflection at the crown being about 12 mm. (0·5 in.).

In 1889 a second Monier pamphlet appeared, written by Captain V. Petrin, in which Koenen's method of calculation was extended.

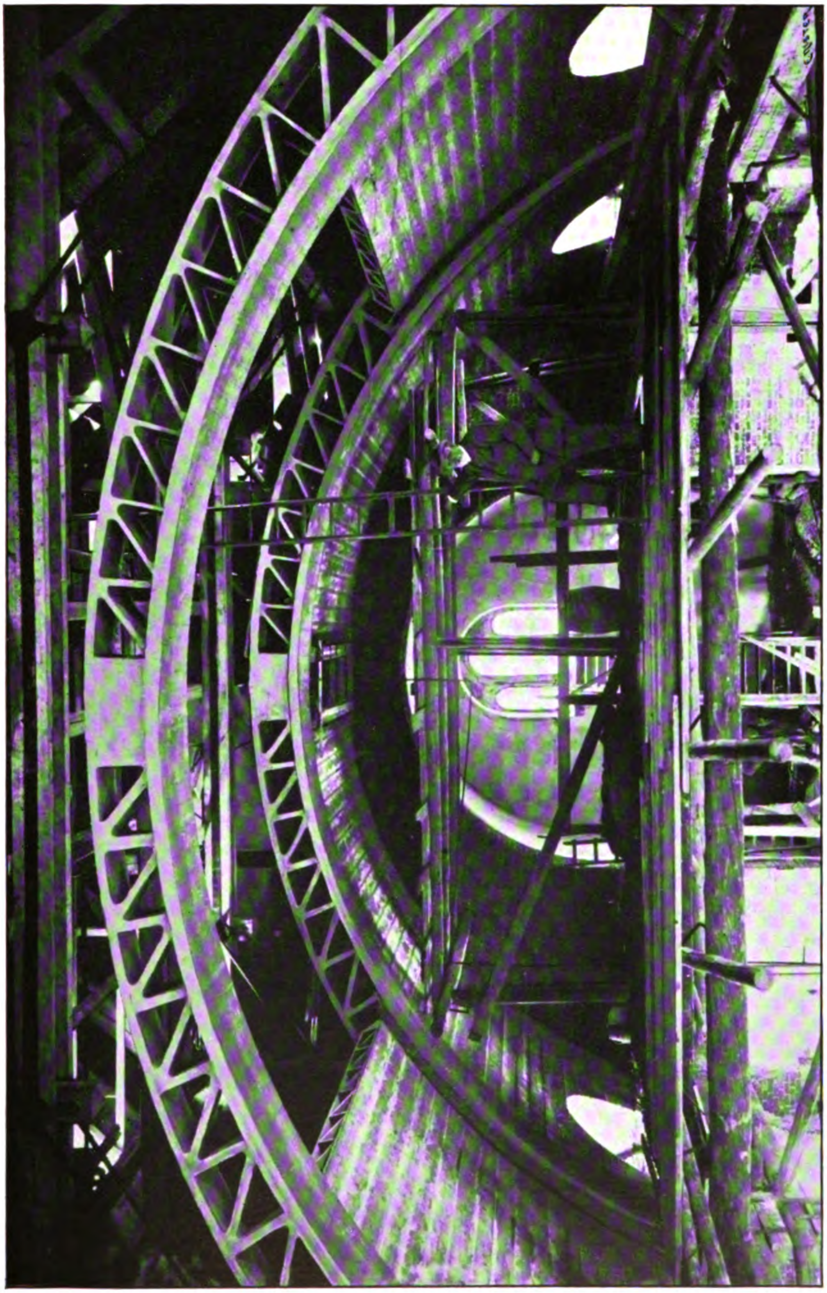
In the same year (1889) a large bridge was also constructed on the Monier system at the Matzleinsdorf railway station. Its breadth was 4 m. (13 ft.), span 10 m. (32 ft. 6 in.), rise of arch 1 m. (3 ft. 3 in.), thickness of crown 15 cm. (6 in.), thickness at springing 20 cm. (8 in.). It broke under premature loading with 10,000 kg. per sq. m. (2,100 lb. per sq. ft.) by shearing at the abutments.

In 1890 an important extension of the theory of reinforced concrete construction took place. In that year the present professor at the German Technical School of Brünn, Herr Paul Neumann, published his memoir on "Calculations in Monier Construction" in the weekly *Journal of the Austrian Association of Engineers and Architects.* Mr. Neumann appears to have been one of the first to recognise the relation between the coefficients of elasticity of the two materials united in the construction, and his mode of calculation thus seems practically to have become the foundation of all those since devised. It is said in the above-mentioned article: "It is possible that the coefficient of elasticity of cement alters with varying stress, and has different values under compression and under tension. But in any case, an even approximately accurate calculation of the Monier construction is only possible by taking into account the unequal coefficients of expansion."

About the same time Prof. T. Melan, then at the Technical School in Brünn, now in Prague, published a treatise on "The Computation of Bending Stresses in Concrete and Monier Construction," in which he suggested, in order to explain the conditions of fracture in Monier structures, that the elastic behaviour of concrete was unlike under pressure and under tension. He calculated from the experiments carried out by G. A. Wayss the ratio of the coefficients of elasticity under compression and tension, and of concrete and steel, and referred the great stability of Monier structures to this property.

Prof. T. Melan has, however, not earned his prominent position in reinforced concrete work by his theoretical labours alone. He is the inventor of the system of construction of concrete floors and vaulting which goes by his name. This invention dates from 1890, and after the grant of the patent in 1892 the first tests to destruction were carried out in Brünn by the firm of Pittel and Brausewetter, who acquired the patents, and who have, down to the present time, constructed a number of interesting bridges on the Melan system. The first loading tests were performed on July 20th and 22nd, 1892, with two arches, each of 2 m. (6 ft. 6 in.) span, 3·20 m. (10 ft. 5 in.) length, 20 cm. (8 in.) rise, and a uniform thickness of 8 cm. (3 in.). Embedded in these were four arched ribs of I-iron (No. 8). This vault could not be loaded to fracture, as at a load of 12,000 kg. per sq. m. (2,520 lb. per sq. ft.) only fine hair-cracks had appeared, and on account of the safety of the workmen the load could not be increased. A second vault, of 4 m. (13 ft.) span, 8 cm. (3 in.) thickness, and the same reinforcement, and of 28 cm. (11 in.) rise, 3 m. (9 ft. 9 in.) in length, broke under a load of 16,400 kg. per sq. m. (4,444 lb. per sq. ft.). Since then Prof. Melan has devised an entirely satisfactory method of computation for his own system, and, as already mentioned, a number of large bridges have been constructed, illustrations of a few of which are presented with this article.

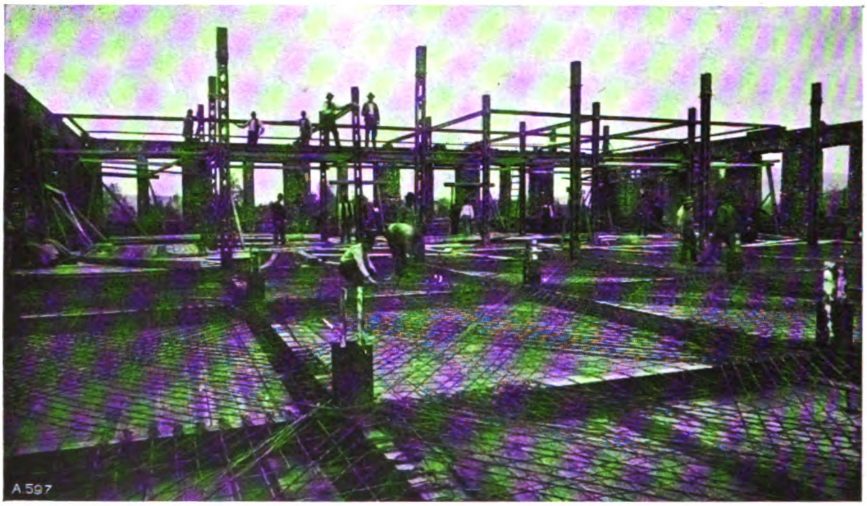
Among the principal of these are: the Payerbach bridge of 26 m. (84 ft.) span, with one hinge; the Franz Josef bridge at Laibach, of 35·5 m. (115 ft. 6 in.), with three hinges; and Steyr, of 42·4 m. (138 ft.), with three hinges. This bridge, like all those of Messrs. Pittel and Brausewetter, is remarkable as being one of the flattest



Vaulting of the Evangelical Church at Aussig, Visintini System.

in the world. With the 42·4 m. span it has a rise of only 2·65 m. (8 ft. 8 in.). The radius of curvature of the arch is 85 m. (276 ft.). The thickness at the crown is 60 cm. (24 in.), and at the springing 70 cm. (28 in.); the thickness at the middle of the semi-arch is 80 cm. (32 in.). The reinforcing ribs lie 1 m. (3 ft. 3 in.) apart, and are lattice arches, 50 cm. (20 in.) high at the crown and abutments, and 70 cm. (28 in.) at the middle of the semi-arch.

These bridges are, however, not the largest; abroad, in Switzerland, Italy, Russia, and America, still larger ones have been constructed. Prof. Melan has also made further advances in theory. His collaboration in the work of the Commission on Vaulting, in the scientific control of the loading tests carried out by that Commission, should be mentioned. Of his other papers and pamphlets may be noticed : " Vaulting of Concrete Combined with Iron Arching Ribs," 1893; " The Theory of Reinforced Concrete Construction," 1896; " Bending Tests of Concrete Floors," 1902; " The Jubilee Bridge at Laibach," 1903; and a large number of greater and smaller writings concerning reinforced concrete construction and other matters.



BUILDING IN COURSE OF CONSTRUCTION FOR MESSRS. SEIDL & CO., ZAUTKE.
Constructed in 1904 on the Matrai System by Messrs. Pittel & Brausewetter.

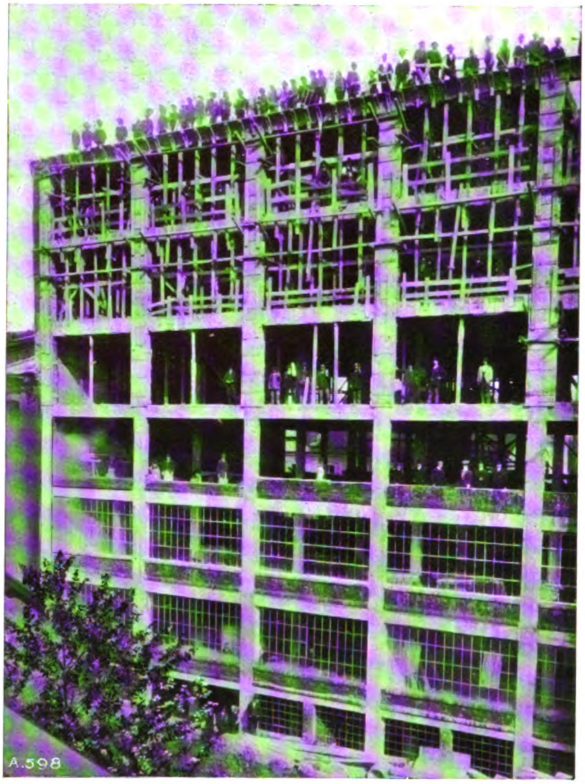
It is impossible to speak of Melan bridges without mentioning Dr. F. von Emperger, the pioneer of this system in America. He founded the Melan Arch Construction Co., and managed it until the end of the 'nineties, executing a number of important structures in this system. These alone would not, however, account for the position which Dr. von Emperger actually occupies in relation to reinforced concrete. This comes rather from the indefatigable zeal with which he has from the beginning of the theoretical work until now pursued the investigation of the stresses existing in the interior of a reinforced concrete structure, with the object of finding a sure basis of computation. Dr. von Emperger may be said to have given the initial impulse to the now so considerable mass of German literature on reinforced concrete. His first memoir was one in 1897, in the *Journal of the Austrian Association of Engineers and Architects,* on " The Theory of Reinforced Concrete Floors," which contains practically the entire mode of calculation appearing seven years later in the

Prussian Official Regulations. He, like many other engineers, came to a turning-point with the Paris Exhibition of 1900. He collected his observations in a work, "New Works and Modes of Construction in Concrete and Steel," which became an efficient means of propaganda, and excited on all hands a lively interest from its exhaustive treatment. Out of it grew *Beton und Eisen,* the leading Continental journal on concrete and reinforced concrete, which Dr. von Emperger edits in a most able and scientific manner. This journal was in its earliest years published in Austria, but was later transferred to a Berlin publishing firm.

In 1904 Dr. von Emperger further founded the *Researches in the Domain of Reinforced Concrete,* and himself wrote Part 3, "The Part Played by Adhesion in Reinforced Concrete Beams," and Part 5, "The Dependence of the Breaking Load on Adhesion, and Means for Increasing the Strength of Reinforced Concrete Beams." Besides these, he has published numerous memoirs in *Beton und Eisen.* In 1906 the *Concrete Calendar* appeared, which now appears annually, and gave rise to the "Handbook of Reinforced Concrete Construction," now about to appear. This work, one part of which has been already published, is to contain an exhaustive description of the modes of application, and also of the theories and calculations connected with reinforced concrete.

PRINTING ROOM AT THE WORKS OF R. M. ROHRER IN BRÜNN,
Showing Floors and Columns which were executed in Reinforced Concrete on the Ast System.

Of other Austrian investigators who have contributed to the advancement of reinforced concrete in Austria down to the present time, we must mention Messrs. Haberkalt, A. Spitzer, Colonel Dr. Mandel, and Prof. R. von Thullie, of Lemburg. The latter has greatly contributed to the elucidation of disputed problems by his numerous papers and experiments.



THE KARL WOLF FACTORY IN BIELITZ.
Floors and Columns constructed in Reinforced Concrete on the Ast System 1906.

We must further mention the work of the various contractors whose careful execution has established confidence on the part of the building public. In most cases these firms have not confined themselves to their commercial interests, but by their encouragement of breaking tests have forwarded scientific objects also. Besides Messrs. G. A. Wayss & Co., already mentioned, one of the oldest firms is that of Messrs. Pittel and Brausewetter. This firm introduced both the Melan and the Matrai systems. Although this latter system is not properly one of reinforced concrete, so many floors have been constructed according to it that mention of it appears desirable.

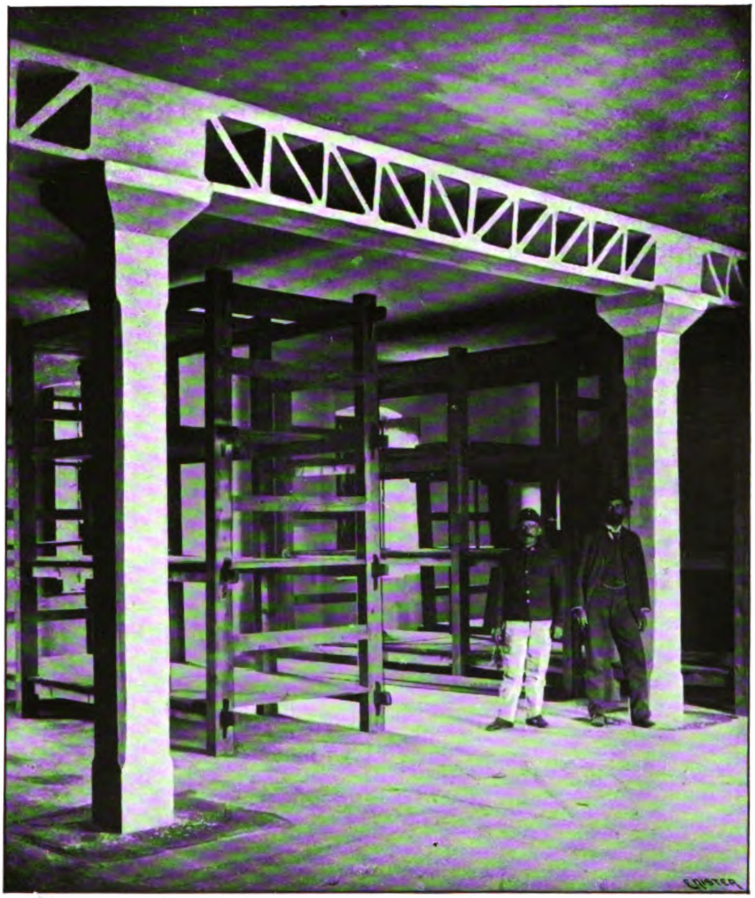
Messrs. Ast and Co. introduced the Considére system, and first applied it in the construction of the Rohrer Printing Works, in Brünn, in 1905. This building is, however, mainly constructed on the Hennebique system—which, by-the-by, does not appear to have ever been patented in Austria—and has its columns of spirally reinforced concrete ("béton fretté") on account of the heavy load which they have to carry. The illustration clearly shows the ground floor columns. The most heavily loaded column has to carry 140,500 kg. (309,000 lb.), and has a diameter of 40 cm. (16 in.) with ten vertical rods 30mm. (14 in.) diam., and spirals of 15 mm. (0·6 in.) wire with fifteen turns to the metre. The heaviest loading in any part amounted to 174,000 kg. (382,000 lb.) on the columns in the basement. These were 50 cm. (20 in.) in diameter,

BRIDGE AT HERZDORF,
Visintini System.

with ten vertical 30 mm. rods and spirals of 15 mm. diam., 13 to the metre. The building consists of five stories, and the floors have to bear an average load of 1,700 kg. per sq. meter (357 lb. per sq. ft.). The works were erected in 1905. To Messrs. Ast and Co. is also due the erection of the largest existing girder bridge, which was constructed at Payerbach in 1903, and has a clear span of 26 m. (84 ft.).

Other prominent firms specialising in reinforced concrete are Messrs. N. Rella and Nephew, of Vienna, and Messrs. Westermann and Co., of Innsbruck.

There is yet one Austrian invention which marks a step forward, and must be mentioned with appreciation, namely, the Visintini system. By his invention Herr Visintini has introduced framed beams into reinforced concrete construction, and has thus greatly assisted its development. The first building in which the Visintini beams were brought into use was the annexe to the Royal and Imperial Cadet School at Lobzow in 1903. In Hungary the Visintini beams were applied in the same year in the stables erected for Count Esterhazy. As conspicuous examples of his system we may mention various barracks, and also the vaulting of the Evangelical Church at Aussig



CEILING OF THE ROYAL BARRACKS AT IGLA,
Visintini System.

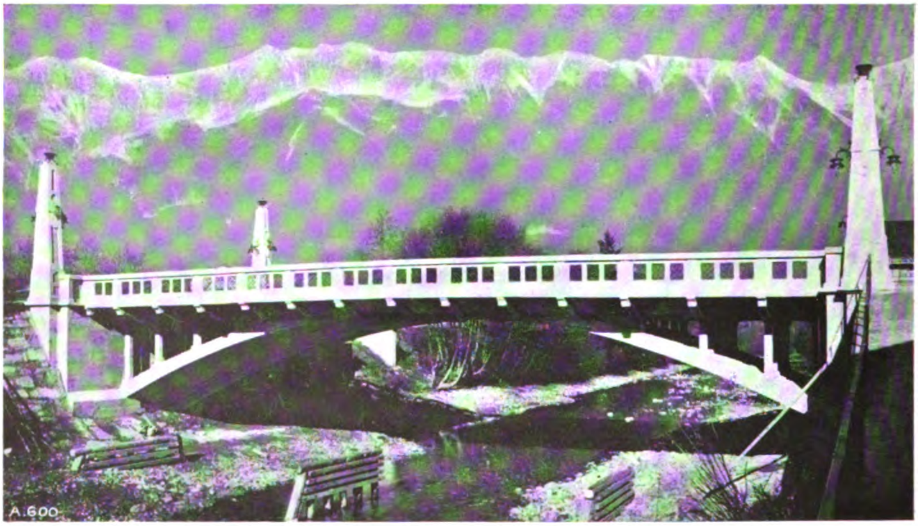
In the latter building arches on the Visintini system were employed for the first time, three arched girders being placed at a distance apart of 4·68 m. (15 ft. 3 in.) from centre to centre, having a span of 12·4 m. (40 ft. 3 in.). They are 60 cm. (24 in.) wide, and have flanges 10 cm. (4 in.) wide on the under side, supporting cross beams. The arches are 60 cm. (24 in.) deep at the crown, and 90 cm. (36 in.) at the abutments, and are connected at the crown by a concrete beam.

Of Visintini bridges, the Herzdorf bridge of 1905 has four spans, one of 22 m. (71 ft. 6 in.) and three of 15 m. (49 ft.) span each. The longitudinal girders are placed 1·5 m. (4 ft. 10 in.) apart from centre to centre. They are 50 cm. (20 in.) wide, 136 cm. (4 ft. 5 in.) high in the main span, and 110 cm. (3 ft. 7 in.) in the other spans. Over these beams transverse girders each 20 cm. (8 in.) wide and 21 cm. (8½ in.) high are placed close together and covered with a floor of reinforced concrete about 4 cm. (1½ in.) thick.

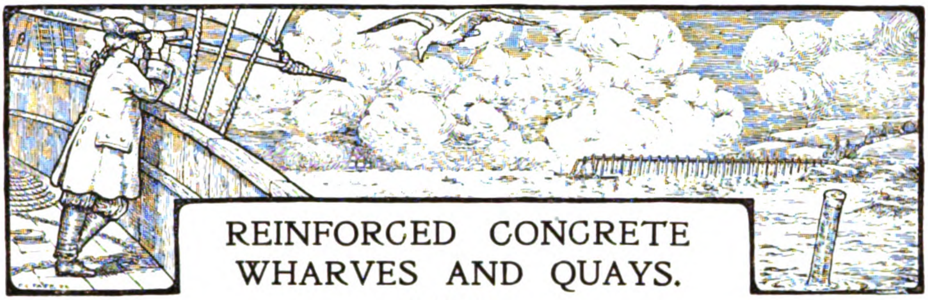
As regards the methods of computation in use, it must be admitted that uniform methods for the whole of Austria do not yet exist. A Commission appointed for this purpose has not yet completed its labours. Up to the present the Prussian regulations have been usually adopted, but certain authorities have published "guides." One of these should be mentioned—namely, the one published in 1903 in connection with the construction of the new Alpine Railway, entitled "Regulations for the Calculation and Execution of Reinforced Concrete Retaining Structures for Open Cuttings."

The conclusion to be drawn is that Austria, both in the past and the present, has rightly appreciated reinforced concrete construction, and has materially advanced it both on the theoretical and the practical side.

There can be no doubt that reinforced concrete will also receive much attention in the future in Austria, for great efforts are being made to introduce it into quarters in which it has not yet found application.



Bridge in Innsbruck,
Constructed by Messrs. Westermann.



REINFORCED CONCRETE WHARVES AND QUAYS.

ARTICLE III.

BY W. NOBLE TWELVETREES, M.I.Mech.E.

We have previously published a series of articles dealing with reinforced concrete bridges by Mr. W. Noble Twelvetrees, and we are now presenting a further short series on the subject of Wharves and Quays, illustrating characteristic examples, both large and small, in which reinforced concrete has been used at home and abroad.

The article in our May issue dealt with examples constructed in France on the Coignet system and in July with two English examples on the Hennebique system.—ED.

DOCK AND QUAYS ON THE CLYDE.

As a final example of reinforced concrete construction of the kind considered in the present series of articles, the writer takes the dock recently completed for the Coventry Ordnance Works on the north bank of the Clyde, at Scotstoun, near Glasgow, and designed so far as concerns the reinforced concrete work by the Patent Indented Steel Bar Co., of Westminster. The new dock is of special interest, because it embodies the first application of reinforced concrete in Great Britain to this particular department of civil engineering.

Dock engineers are sometimes credited with undue conservatism, but we are not prepared to endorse criticism of the kind, for the satisfactory reason that the problems associated with the design and practical construction of dock and quay walls are of serious character, that the forces brought into play, sometimes in a most unexpected manner, are practically irresistible, and that any departure from practice which long experience has shown to be prudent, may involve the most serious consequences.

These facts are quite sufficient to account for the small extent to which reinforced concrete has been applied up to the present time in dock engineering. No doubt there are many cases in which nothing could be gained by the incorporation of steel in concrete, as, for instance, where the weight of the last-mentioned material is absolutely necessary for the purpose of resisting earth pressure, and the concrete construction is of such proportions as to provide more than amply for the comparatively small tensile stresses developed. On the other hand, it frequently happens that by the judicious employment of steel the weight of concrete that would otherwise be necessary can be reduced very materially, and so leads to important savings.

While believing firmly in the advantages of reinforced concrete, the writer does not shut his eyes to the fact that this combination is not always more economical than plain concrete. The market price of steel, the cost of skilled labour, and the direct or indirect royalties to be paid for the use of patented systems of construction or patented types of reinforcement may counterbalance the amount likely to be saved by the quantity of plain concrete displaced by a given percentage of steel. While things may work out thus, it does not follow that they will always do so, and as experience and faith in reinforced concrete are gradually increased, dock engineers will probably discover that forms of design to which they have long been accustomed may be modified with advantage to all concerned. The Scotstoun Dock being a new departure in this direction, deserves close consideration, and in order that designers may have full information of its structural features, we give as illustrations to this article reproductions of drawings where the number, dimensions and position of the reinforcing bars are clearly shown for every part of the work.

Fig. 1 is a plan of the dock and quays on the east and west side respectively. The site measures 387 ft. long along the river front, by about 230ft. from front to back. On the E. of the dock there is a straight quay wall about 188 ft. long, and on the W. one 47 ft. long, the curved entrance to the dock being 152 ft. wide.

The dock itself is 48 ft. wide, this measurement commencing at the distance of 40 ft. from a line connecting the river quay walls, and the parallel part of the dock of approximately semi-circular form at the further end is 176 ft. long. Behind the river quay walls and on either side of the dock are various engineering workshops of the Coventry Ordnance Works, the general arrangement of which is shown in *Fig.* 2.

It may be mentioned, however, that the foundations of these buildings are partly supported on timber piles, some of which are shown in *Fig.* 1.

Commencing at the extremity of the east quay, it will be seen by reference to *Fig.* 1 that the wall is 7 ft. thick at the top, with an outside batter increasing the thickness to 10 ft. at the bottom. These dimensions apply for the length of 188 ft. in which the wall is strengthened by three counterforts, of which the first measures 10ft. long by 6ft. wide, and the other two are 12ft. long by 3 ft. wide. After entering the curve at the dock entrance the thickness of the wall is maintained until the middle of the curve has been passed, and is reduced thereafter to the thickness of the wall on the east side of the dock proper. At the back of the curve a counterfort of the form indicated in the plan has been built so as to afford ample security against injury by vessels entering the dock.

The shorter quay wall on the west side of the entrance is 7 ft. thick at the top, 10 ft. thick at the bottom, and has one counterfort at the extremity with the dimensions of 12 ft. long by 6 ft. wide. As in the case of the east curve, the entrance wall is strengthened by a massive counterfort, and the thickness of the wall itself is gradually reduced down to that of the parallel portion of the dock.

Along the sides and end of the dock are three stepped walls of the following thickness;—Top, 3 ft.; 1st step, 5 ft.; 2nd step, 8 ft.; 3rd step, 11 ft. 6 in. Below the 3rd step the thickness is increased to 13 ft. 4 in. by the batter of the front face.

At intervals of 27 ft. apart centre to centre each side wall is strengthened by fourteen counterforts, which in plan have the dimensions of 27ft. by 9 ft. on the east side, and 33 ft. by 9 ft. on the west side where the earth is of less stable character. It will enable the reader better to understand the construction of the fourteen counterforts if we explain that the outside part of each is designed for supporting one of the columns and stays of a gantry for the travelling crane over the dock. The portions so employed were constructed first and the dovetailed joint is intended to provide a good bond between the two portions of the concrete work. The outer wall along the end of the dock is built monolithic with the semi-circular wall filling up the two corner angles, and no counterforts were necessary. Six bollards for warping and mooring vessels are provided in the positions indicated on the plan, two at the entrance, two about the middle of the length, and two at the further end.

From the foregoing description it should be clear that the design taken as a whole represents sound and substantial construction, and dock engineers will probably agree with the view more fully when we add that the whole work is in monolithic concrete, the lower portion without reinforcement, while the upper parts of the walls are reinforced by steel bars in such manner as to give ample resistance to tension wherever developed, to guard against temperature cracks, and to tie the counterforts securely to the walls where connexion of the kind is desirable.

Before passing on to the other drawings, let us briefly examine the nature of the reinforcement represented in *Fig.* 1. To avoid unnecessary repetition we may here

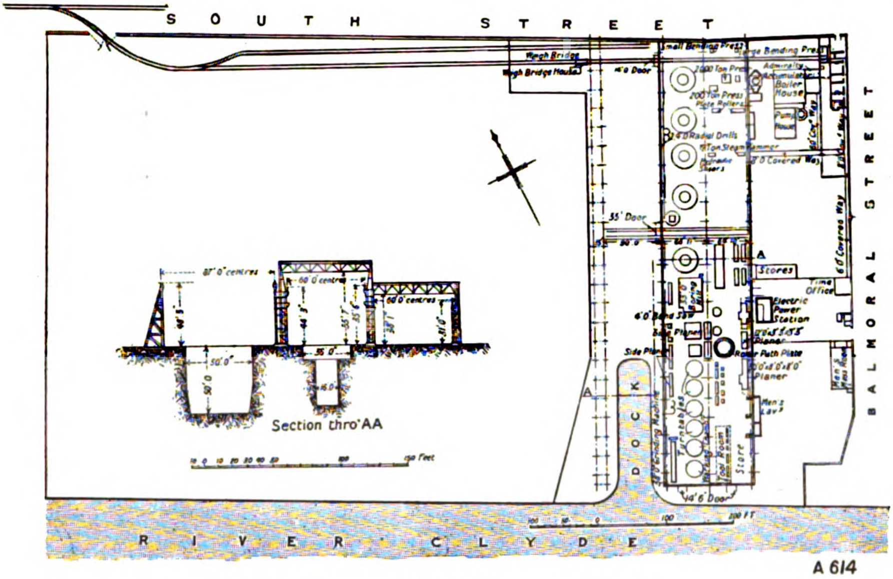


FIG. 2.

state that in every case where the word "bars" is employed, it should be understood that we mean patent Indented bars, as illustrated in *Fig* 3, the cross sectional areas and weights of the different sizes being as follows :—

Size.	Net section.	Weight per ft. run.	Size.	Net section.	Weight per ft. run.
¼ in.	0·06 sq. in.	0·24 lb.	¾ ,,	0·56 ,,	1·91 ,,
⅓ ,,	0·11 ,,	0·38 ,,	⅞ ,,	0·77 ,,	2·60 ..
½ ,,	0·25 ,,	0·85 ,,	1 ,,	1·00 ,,	3·40 ,,
⅝ ,,	0·39 ,,	1·33 ,,	1¼ ,,	1·55 ,,	5·31 ,.

On behalf of this type of reinforcement, which we may mention was employed throughout the Galveston sea wall in the United States, it is urged that the mechanical bond offered is a point of great importance in heavy work, and especially in structures where the concrete is exposed to the action of sea water, whose tendency may possibly have the effect of impairing the efficiency of the adhesion between the concrete and the steel unless the former material is of such proportions and so carefully deposited and rammed as to render it impermeable. Another argument is that the effect of the mechanical bond is to distribute strains induced by temperature changes of the whole length of each reinforcing bar, and so obviate any cracks save those of minute dimensions which will not permit the penetration of moisture to the interior of the concrete.

Commencing as before with the east river quay, we find that four 1-in. bars are laid horizontally near the top at the front and four similar bars at the back of the wall. Below the four bars at the front the concrete is reinforced by ¾-in. bars, also laid horizontally at intervals of 12 in. apart centre to centre measured vertically, these bars being disposed in three groups continued down to different levels, as will be explained later. The river face of the wall is further reinforced by ½-in. vertical bars of different lengths spaced 24 in. apart, and the landward face by ¾-in. vertical bars ranging in length from 24 ft. to 50 ft., these bars being situated in three series between the counterforts. Each of the first two counterforts from the east is reinforced by twelve vertical ¾-in. bars, 24 ft. long, and the third counterfort by twelve vertical 1-in. bars 41 ft. 6 in. long. The counterfort behind the curved wall at the eastern side of the dock entrance is reinforced by a series of 1-in. horizontal bars bent at the face of the river quay, for resisting shearing stresses, these bars being spaced 12 in. apart and applied for a sufficient distance below the surface.

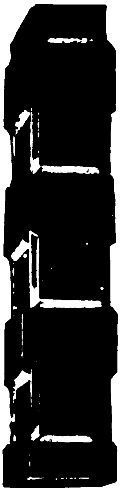


FIG. 3.

The river wall on the west of the dock is reinforced by four 1-in. bars near the top at front and back. The river face is further reinforced by ¾-in. horizontal bars spaced 12 in. apart and by ½-in. vertical bars 50 ft. long spaced 24 in. apart. The landward face between counterforts is reinforced by twenty-seven ¾-in. vertical bars 50 ft. long, the western counterfort by twelve 1-in. bars 49 ft. 6 in. long placed vertically, and shearing stresses in the counterfort behind the curved entrance wall are taken by a series of 1-in. bars spaced 12 in. apart, the series being continued for a sufficient distance below the surface for resisting shearing stresses as in the case of the opposite entrance wall.

The curved walls at the dock entrance and the parallel walls on each side of the dock are reinforced by four 1-in. horizontal bars near the top of each face, the front face in all the walls being further reinforced by ¾-in. horizontal bars disposed at the distance of 12 in. apart as far down as the lower surface of the concrete in the counterforts. Between counterforts 6 to 13 the inner curve at the end of the dock is reinforced by ¾-in. horizontal bars 12 in. apart centre to centre, carried down to the bottom of the counterforts. Vertical ½-in. bars, 36 ft. long, are disposed at the distance of 24 in. apart centre to centre in the concrete of the walls facing the dock.

In order to provide for the adequate connexion of the dock walls and counterforts, two vertical series of ¾-in. horizontal tie bars 13 ft. 6 in. long 12 in. apart centre to centre are carried from each rectangular counterfort into the dock walls, the end of each tie being bent and hooked over the horizontal bars of the face reinforcement.

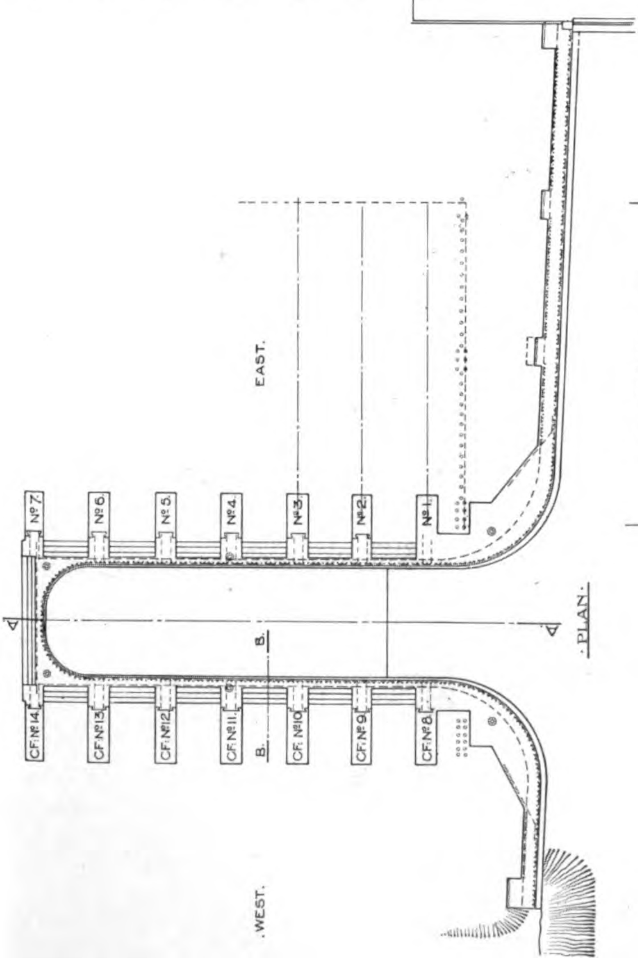
Having now a general idea of the design, we can turn to drawings illustrating the construction in further detail.

Fig. 4 is a front elevation showing the reinforcement of the river and dock entrance walls. The normal ground level is little more than 4 ft. above the high water level of ordinary spring tides and about 3 ft. below the highest known tide. Consequently an essential feature of the new work was to establish the quay level at the height of 6 ft. 2 in. above the highest known tide, and thus to provide for the erection of workshops on a site where they would be free from the risk of inundation.

To provide sufficient depth of water at all states of the tide the mud has been dredged away, as represented in *Fig.* 4, and to guard against any tendency of the soft material to slide down from the east, a spur has been built out from the extremity of the quay to act as a retaining wall.

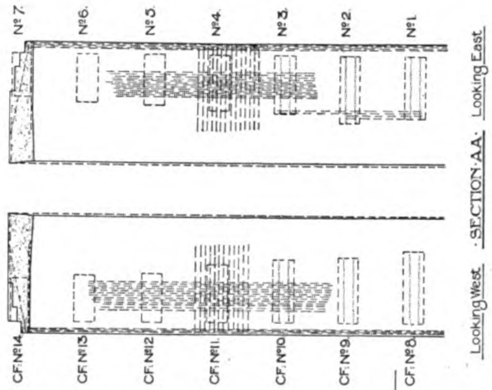
The east river wall may be regarded as including four sections, the first, 100 ft. long by 28 ft. high; the second, 32 ft. long by 34 ft. high; the third, 32 ft. long by 42 ft. high; and the fourth, joining the curved entrance wall, 24 ft. long by 50 ft. high. The curved part, struck to the radius of 40 ft., is 50 ft. high. To supplement the particulars of the reinforcement already given we add the following notes.

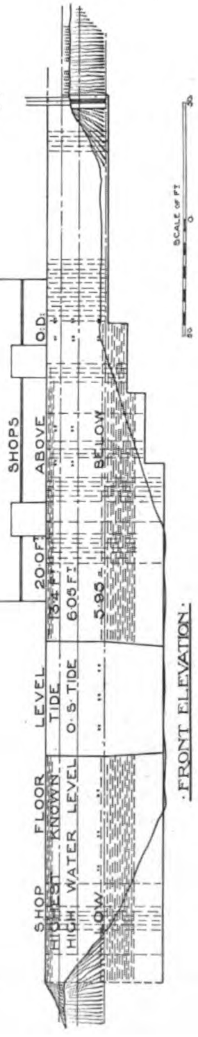
FIG. 1.



·PLAN·

FIG. 5.





·FRONT ELEVATION·

FIG. 4.

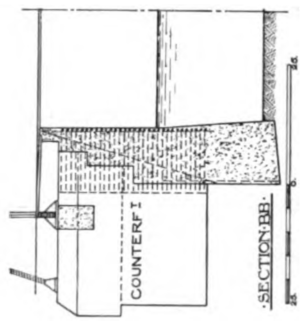


FIG. 6

In the first section of the river wall there are forty ½-in. vertical bars 28 ft. long, and a series of ¾-in. horizontal bars down to the bottom completing a meshwork of steel which extends from top to bottom of the wall near the river face.

In the second section of the same wall there are fourteen ½-in. vertical bars 34 ft. long, and a series of ¾-in. horizontal bars down to the bottom. In the third section there are fifteen ½-in. vertical bars 42 ft. long, and a series of ¾-in. horizontal bars down to 31 ft. from the top of the wall.

It should be noted that the ¾-in. horizontal bars in every case commence below the four longitudinal 1-in. bars disposed along the top of the wall, and that in the higher sections of the wall the lower part of the concrete is not reinforced.

In the curved portion of the work there are forty ½-in. vertical bars between the end of the river wall and counterfort No. 1 and the network of reinforcement is completed by the ¾-in. horizontal bars extending down to 31 ft. from the top, as in the case of the river wall.

Turning next to the river and entrance walls on the west side we find the height to be 50 ft. throughout, the reinforcement consisting of twenty-six ½-in. vertical bars in the river wall, forty ½-in. vertical bars in the curve thence to counterfort No. 8, and ¾-in. horizontal bars carried down to the depth of 35 ft. 6 in. below quay level. These bars, as before, are in addition to the four 1-in. bars at the top of the wall.

The depths of water at the entrance and in the dock are 36 ft. at high tide and 24 ft. at low tide. *Fig.* 4 shows the profile of the parallel dock walls where the batter is considerably reduced from that along the river quay.

Fig. 5 is a longitudinal section on the line AA (*Fig.* 4) with the exception of the section at the left-hand end, which is an elevation of the wall on the eastern side of the dock. The section here mentioned is the same as that in the side walls of the dock and needs no detailed comment, but it may be pointed out that the ½-in. vertical bars of the reinforcement, spaced 24 in. apart centre to centre, extend down to 37 ft. below quay level, and the ¾-in. horizontal bars, 12 in. apart centre to centre, to 25 ft. from the same level. The end and side walls are further reinforced by diagonal ¾-in. bars disposed as represented in *Fig.* 5, theese bars being spaced 18 in. apart.

The ½-in. vertical bars are 37 ft. long throughout and spaced 24 in. apart centre to centre. The horizontal ¾-in. bars spaced 12 in. apart, as elsewhere, are only applied as far down as the bottom of the various counterforts, and above them are four 1-in. bars running along the top of the quay.

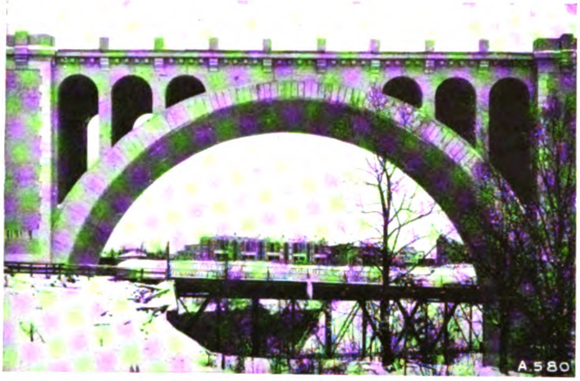
Counterforts Nos. 1 to 7 commence at the distance of 5 ft. below shop floor level and vary considerably in depth, although all of them have the uniform width of 9 ft. The following are the depths of the east wall counterforts below shop floor level :—No. 1, 31 ft.; No. 2, 32 ft. 9 in.; No. 3, 29 ft.; No. 4, 28 ft.; No. 5, 26 ft.; No. 6, 25 ft.; No. 7, 25 ft. Those on the west wall also differ in depth.

The following are the depths of the west wall counterforts below shop floor level :—No. 8, 35 ft. 6 in.; No. 9, 32 ft. 9 in.; No. 10, 31 ft. 9 in.; No. 11, 29 ft.; No. 12, 25ft.; No. 13, 24 ft. 6 in.; No. 14, 22 ft. 6 in.

In *Fig.* 5 may be seen the two series of tie-bars in each counterfort, the arrangement being shown more clearly in *Fig.* 6, which is a section through the west dock wall between counterforts Nos. 10 and 11.

This section illustrates the manner in which the outer part of the counterfort carries the gantry supports mentioned above, the upper part of the concrete being reinforced and the lower part plain and resting upon solid rock. Reference to *Fig.* 2 will make clear the nature of the gantry supports on each side of the dock.

The Connecticut Avenue Bridge Washington, U.S.A.



So much is being considered at the moment in connection with reinforced concrete that the interesting problems arising out of simple concrete, and of concrete in block form, are almost being overlooked. For this reason we published in the preceding issue particulars of the plain concrete domes of the Westminster Cathedral, and in this issue we present an American example of a concrete bridge, which may almost be termed a concrete block bridge, and in which steel reinforcement has only been used in the very slightest degree, and then only for minor purposes.

As an example of concrete bridge construction we hold the Connecticut Avenue Bridge one of the most perfect in existence, well devised and most carefully executed.

The description we publish consists simply of a plain statement of facts, as received from America, without claim to literary veneer, but these facts, plainly put forward in the shortest possible words, contain data that should be of considerable use to engineers and others for reference.

We are indebted for these particulars to Mr. W. J. Douglas, Engineer of Bridges, Washington, D.C., and from the complete set of photographs and plans placed at our disposal we have reproduced those which we think will be of primary interest to our readers.—ED.

THE Connecticut avenue bridge was designed by the late George S. Morrison under competition. After his death the plans were perfected under the direction of Colonel John Biddle, U.S.A.,* and Captain H. C. Newcomer, U.S.A., E. P. Casey, Consulting Architect; R. Hinton Perry, Sculptor. The work of drawings, the plans, and the work of actual construction came directly under W. J. Douglas, Engineer of Bridges, D.C., and F. A. Perley, Assistant Engineer of Bridges, D.C., assistants to Colonel John Biddle, U.S.A., and Captain Jay J. Morrow, U.S.A.

The bridge consists of five 150-ft. arches, separated from each other by 20-ft. piers, and at each end of this series of arches there is an 82-ft. arch. The 82-ft. arches are separated from the 150-ft. arches by an abutment having a width of 37 ft. At the ends of the bridge proper there are two abutments about 136 ft. in length.

The work of building the bridge was executed by the District Construction Company of Washington, D.C.; total cost of bridge, exclusive of land, will be £170,000†; width of bridge, 52 ft.; maximum elevation of floor of bridge above ground, 130 ft.; number of cubic yards of masonry, approximately, 80,000; cost of masonry to the District of Columbia, about £2 10s. per cubic yd.

The bridge was built from crushed stone taken from a quarry about 400 ft. from the site of the bridge. The fact that the successful bidder had an option on the quarry gave him an advantage over the rest of the bidders of about £6,000. All

---

*U.S.A. = United States Army; *i.e.*, the equivalent to R.E.

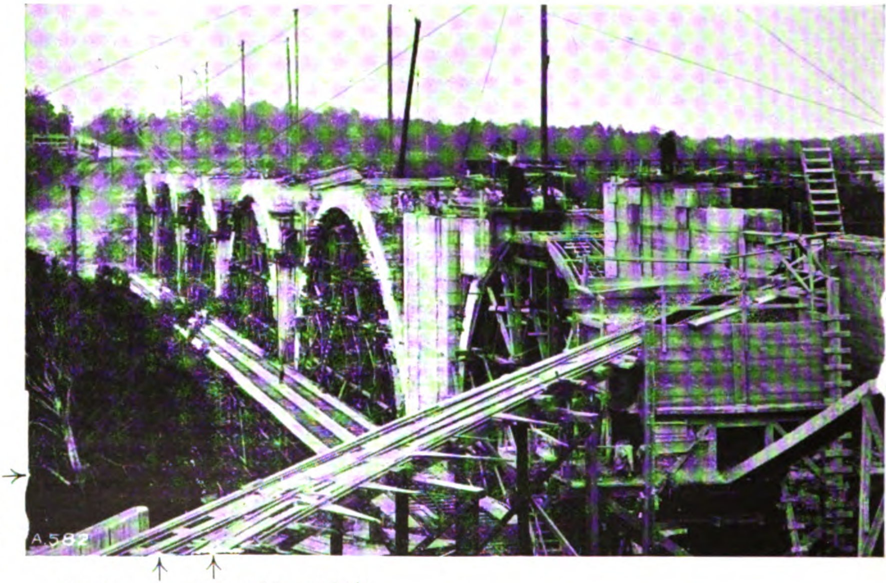
† In arriving at the cost five dollars have been taken as equal to a sovereign.

foundations were carried to hard rock or to very hard rotten rock, with the exception of the head wall of the south abutment. The average depth of foundations below the surface of the ground was 22 ft., and the concrete was made and mixed by a gravity mixer.

The bridge was built by means of nine derricks, four of which had a mast and boom, approximately 70 ft., and the other five masts and booms were, approximately, 90 ft. Concrete was delivered from mixer on a double track parallel to the axis of the bridge, extending for almost its entire length. The derricks practically all the time were on the centre line of the bridge and were jacked up from time to time as the work progressed.

It will be seen from the photographs and plans that the bridge is trimmed throughout with concrete block which very closely simulates granite. Bids were taken for granite trimmings as well as for concrete ones, but the bids were so high it was necessary to use concrete trimmings throughout. These trimmings were cast on a platform 100 by 110 ft. It was required under the contract to bush-hammer all of the trimming stone and also the balance of the bridge structure. The trimming blocks were cast so that all showing faces of the same were either cast down or against the vertical sides of the forms. The trimming blocks were faced with a mortar consisting of one part cement to three parts crushed stone, facing being 1 in. in thickness. The balance of the structure between trimming block stones was faced with ordinary sand mortar, 1 : 3.

View shows 5-150 arches completed.
The near (82ft.) arch is building.



Stone and sand bin.

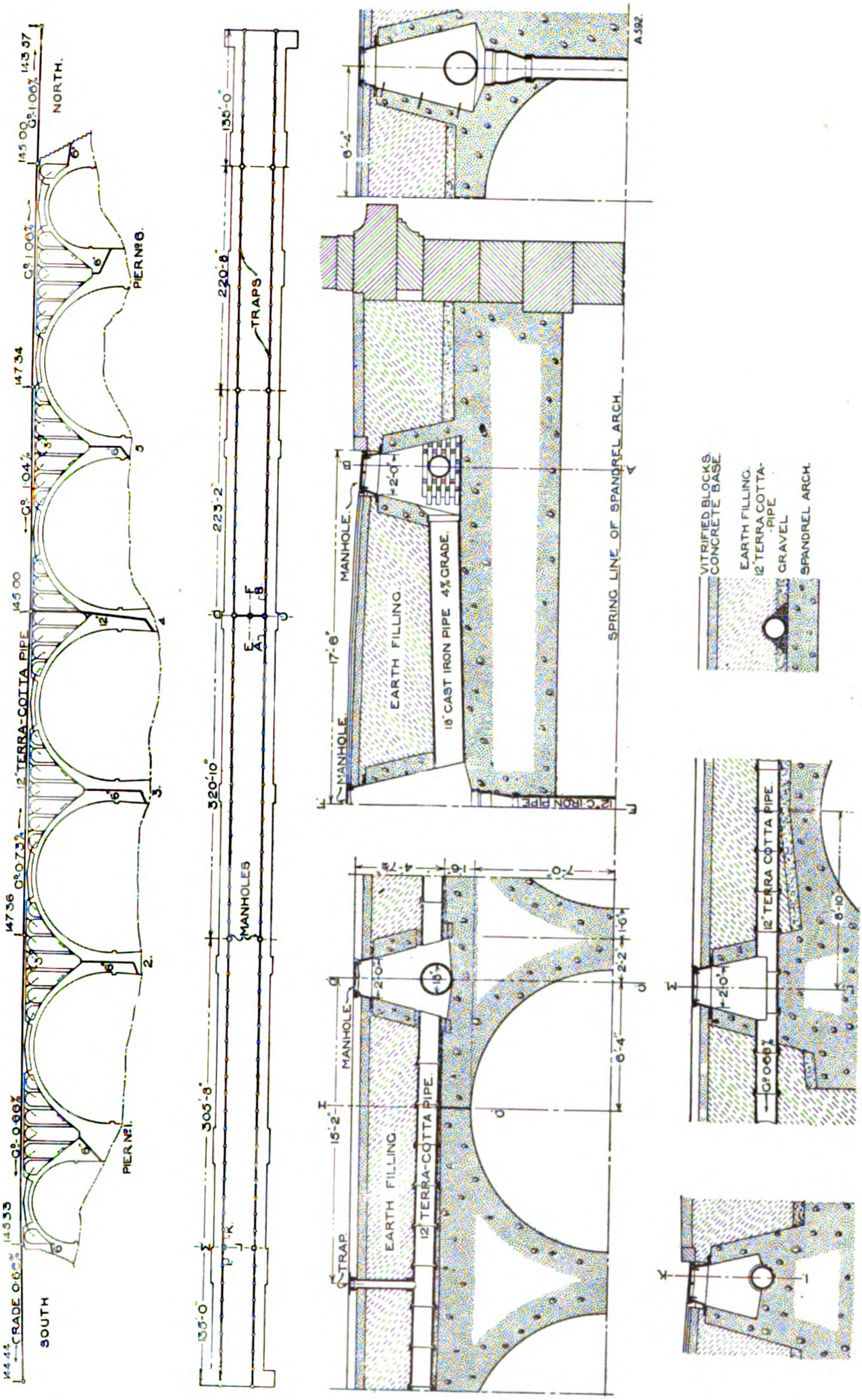
Cement chut cement furnished in bags Gravity mixer

Shows faintly the trimming blocks at the point where they were cast and trimmed.

Tracks to stone pile and to sand pile.

NOTE.—That after concrete was mixed it was dumped into a bucket by gravity. Bucket then carried on flat car (by gravity) on one of two tracks which paralleled the bridge. Bucket of concrete then hoisted by derrick to point of deposit.

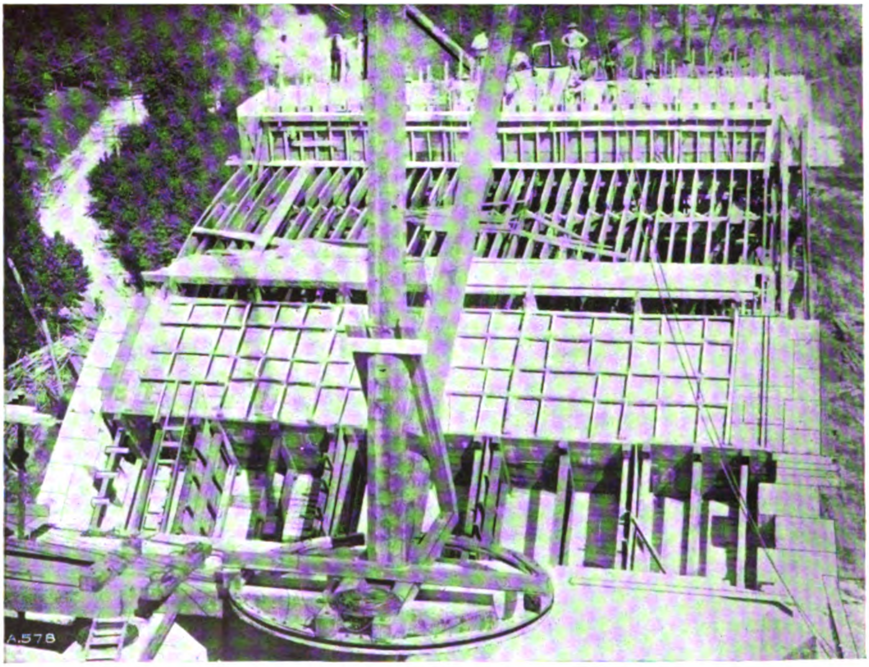
The forms for the entire work consisted of 1-in. tongued and grooved lagging, held in place by studs about 2 ft. on centres and they in turn held by wales, and the



Details of Drainage System.

wales in turn were held by bolts, the outer portion of which was removed when the forms were taken down. The abutments were built in five sections, the head wall was made in one section, with portions of the adjacent wing walls, and the balance of the wing walls were divided into two parts of about 50 ft. in length, thus forming expansion or contraction joints about every 50 ft.

The expansion joints worked winter and summer, opening up as much in winter as one-eight inch. The centres for the five main arches were built at one time, and the centre for the small arches (82-ft. span) was built separately. Total cost of centering to the District of Columbia was £10,800. About 1,500,000 board ft. of

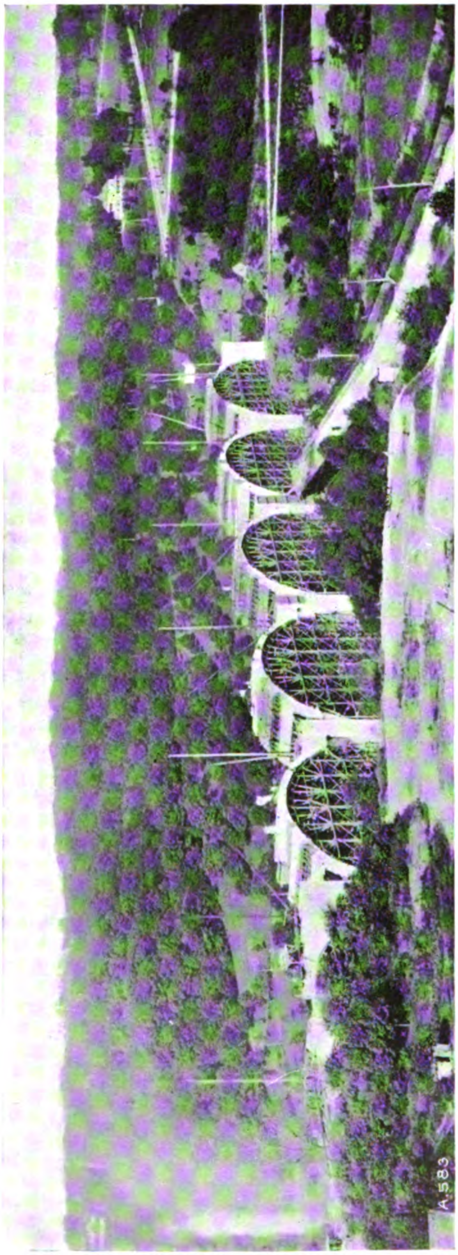


Showing derrick and engine or hollow pier.
The derrick is provided with a swing-wheel.

Shows facin
concrete block
and limbe
sheet suppor
ing block abov

lumber was used. Lumber was kept wet during the concreting of the main arches in order to cut down the liability of fire and to make the striking of the centres somewhat easier. Cost of the erection of the centre was about £3 a thousand ft. below the deck, at which point the bow proper begins. Work above the deck cost about £5 a thousand ft. Both of the above costs are exclusive of material. The centre, as a rule, rested on pile foundations. The posts of the centre were supported by four piles (to each post) with the exception of the first line of posts adjacent to the spring line, which posts were supported each by two piles. Concrete foundations, however, were put in Rock Creek and on the line of Woodley Lane bridge, where it was impracticable to drive piles. A good deal of difficulty was found in driving piles through ground which consisted mostly of rotten rock, and it is thought it would have been more economical if the contractor had used concrete foundations throughout. Where

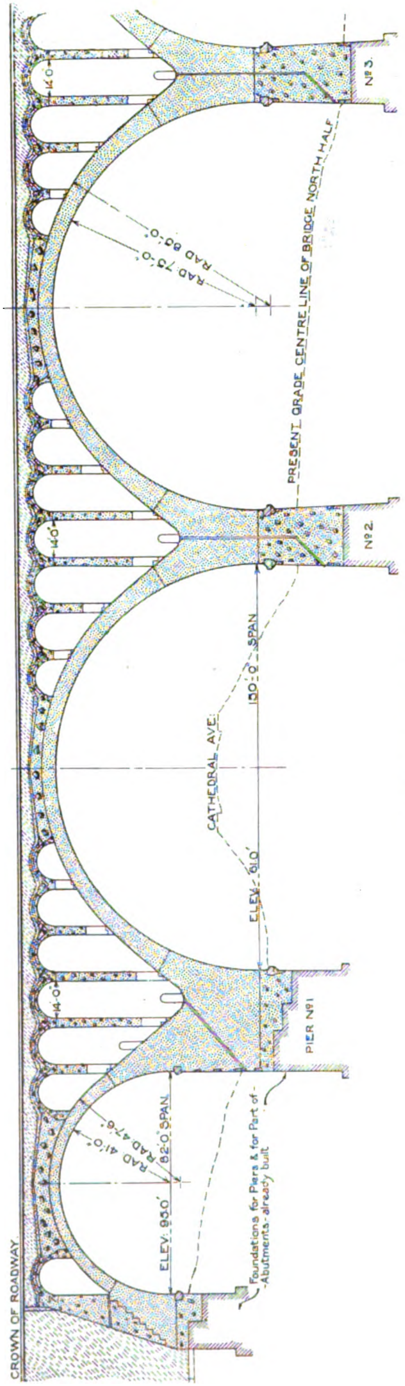
Connecticut Avenue bridge passes over the small steel bridge shown in the photograph (Woodley Lane Bridge) it was not thought economical to take down this bridge, and a survey was made by the Assistant Engineer showing the position of the vertical posts in order to clear the chords and sway braces of the steel bridge.



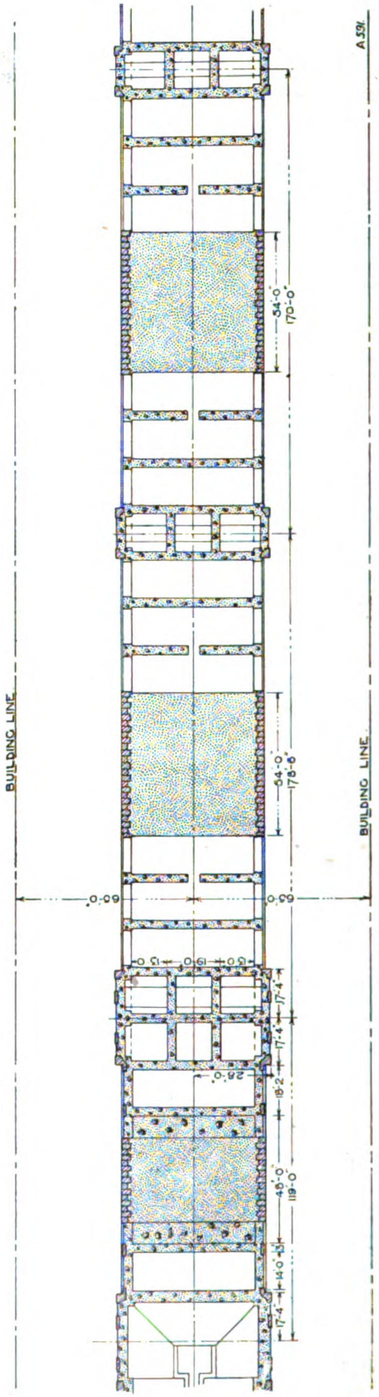
In process of construction, showing alternate block construction and props supporting same. Both the derricks and operating engines were placed upon the piers during construction.

In order to keep track of the settlement of the centre gauge rods were designed, which were fastened to the lagging. These rods were made of 1-in. by $1\frac{1}{2}$-in. lumber. They were fastened to the lagging which formed the soffit of the arches and extended down to within a few inches of the ground. The distance of the end of each gauge rod from fixed points in the ground was read or measured before the work of concreting the arch was begun. These distances were recorded, and as the work of concreting progressed the relations of the ends of the gauge rods, with respect to the fixed points in the ground, were read in order to determine the amount of deformation of the centres as the load of the concrete was brought upon the said centres. The maximum settlement at the crown was $3\frac{1}{4}$ in., minimum $2\frac{1}{2}$ in. These gauge rods were placed at each post on the outside line of posts and each post of the centre line of each centre. The concrete in the transverse blocks was placed in horizontal layers as a rule, and it is the judgment of the engineers in charge of this work that it is better to build all of the transverse blocks in horizontal layers.

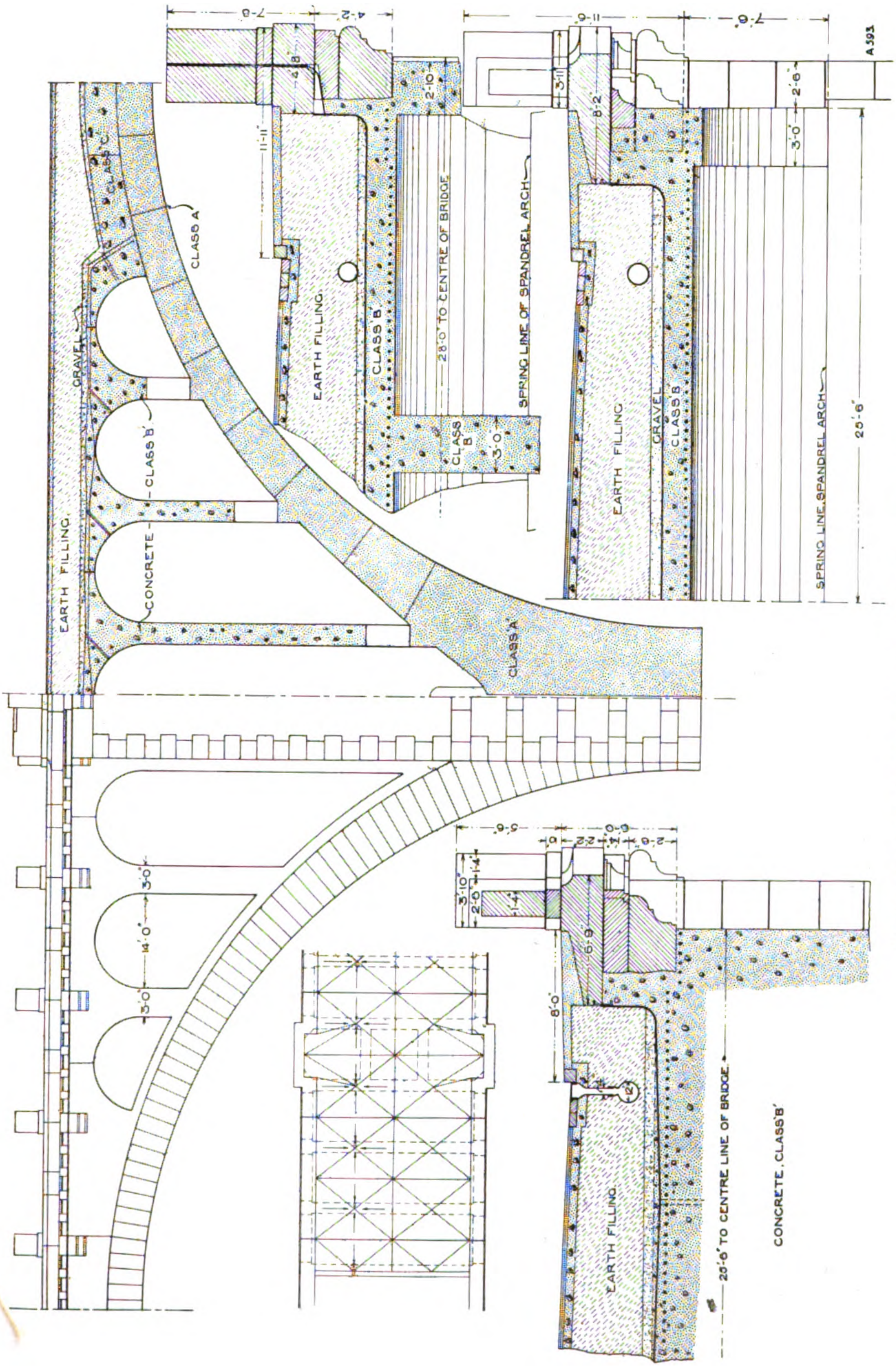
A good deal of difficulty was found in building these large concrete arches with



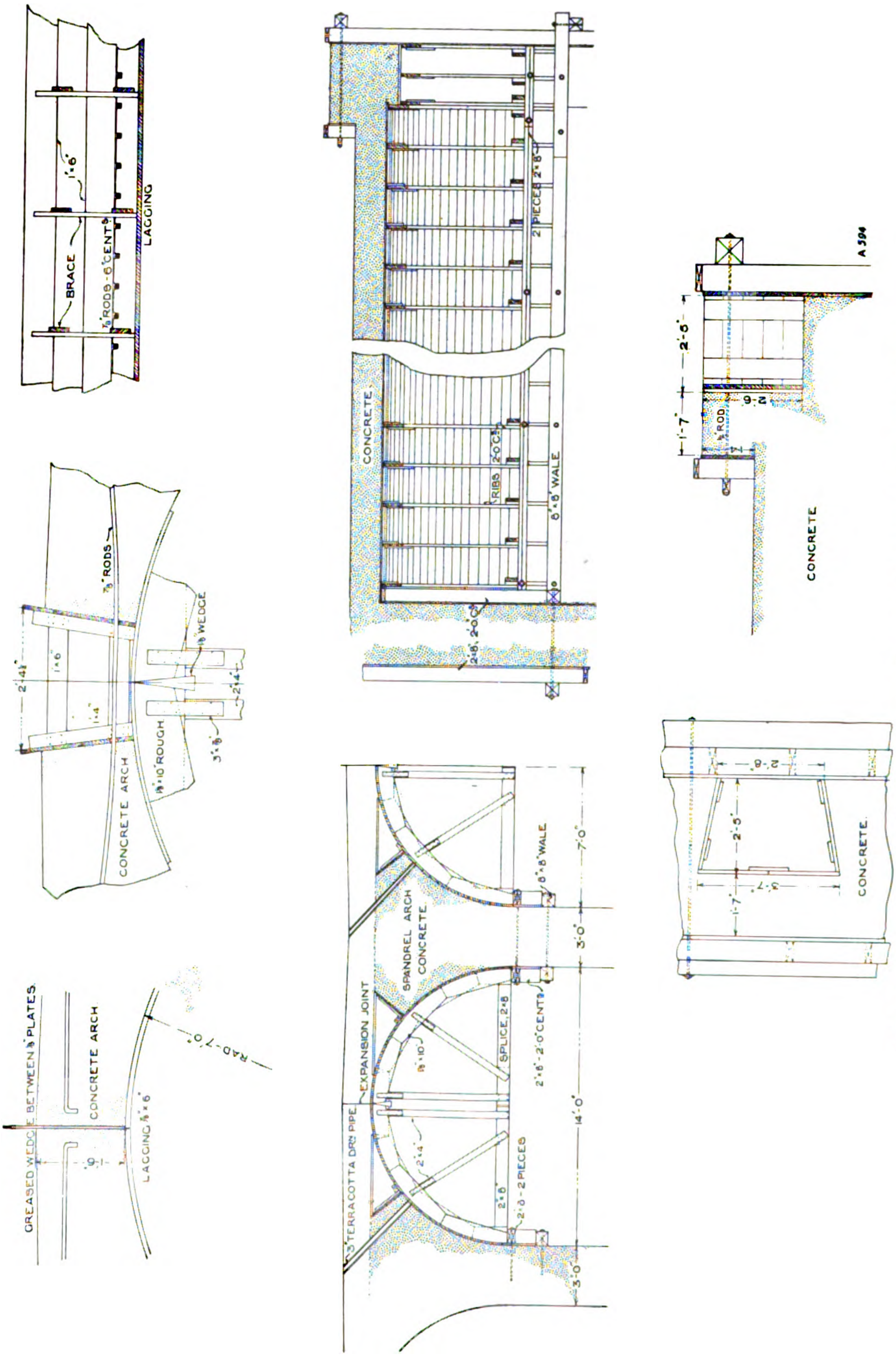
Longitudinal Section.



Section at Spring Line of Spandrel Arches.



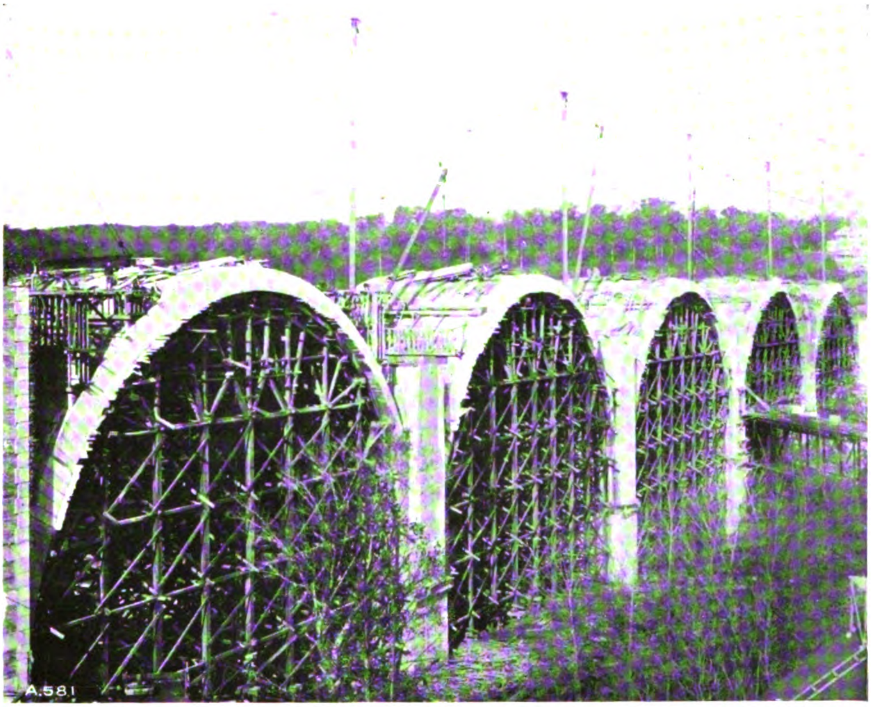
DETAILS OF CONSTRUCTION OF SPANDREL ARCHES.



DETAILS OF CENTERING FOR SPANDREL ARCHES SHOWING POCKETS FOR CONCRETE BLOCKS.

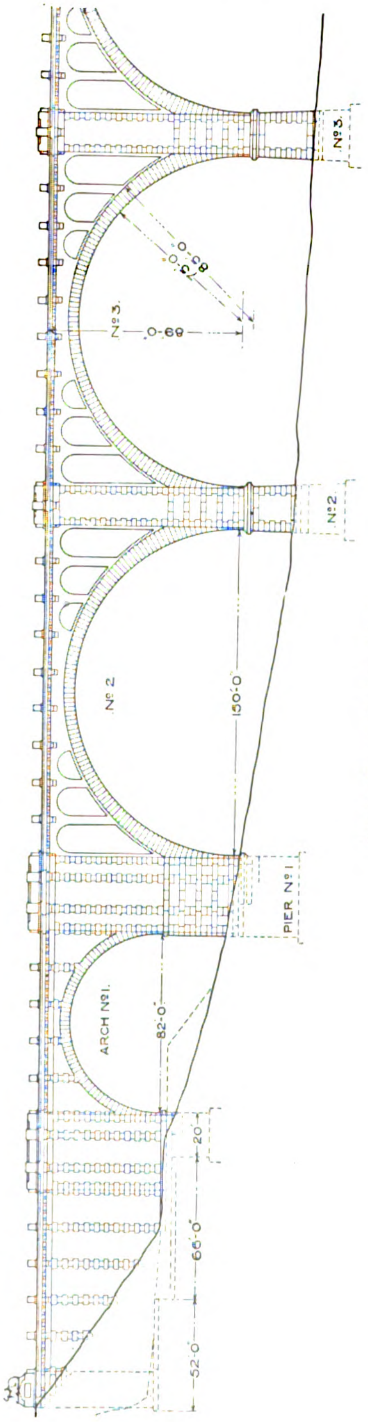
a facing of concrete blocks, on account of the fact that the edges of the concrete blocks are liable to chip off when any concentrated pressure is brought on them.

In order to permit this arch-ring (*i.e.*, the facing concrete blocks) to deform as the centering settled under its load, lead joints were placed in the arch-ring at points corresponding with the joints of the large transverse blocks in the concrete sheeting back of the arch-ring or face blocks. This was done in order to cut down the stresses of erection in the arch-ring and to prevent concentrated pressures on the faces of the concrete blocks. Back forms were necessary up to an angle of about 45 degrees from the spring line, after which the concrete was made somewhat dryer and back forms were not used. Large blocks 6 and 7 were each built in five sections in order to permit the taking out of the timber struts which supported the blocks above these blocks 6 and 7. The intermediate sections were first permitted to set up, after which the wooden struts in the other sections were taken out and these sections finally concreted in.

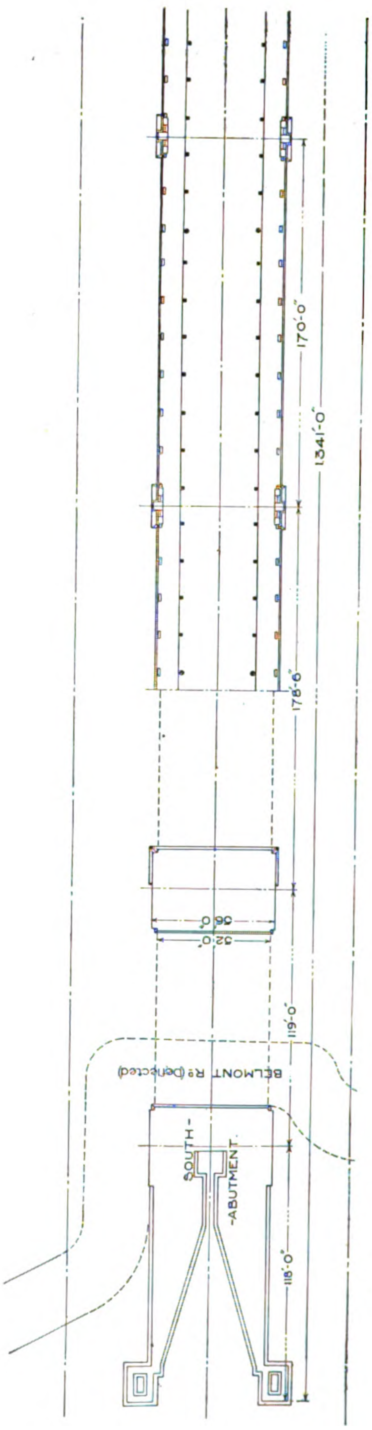


SHOWING CENTERING AND THE FORMS FOR THE SPANDREL WALLS.

After the completion of the main arches the spandrel arches were completed. These spandrel arches are not true arches, the first and third arch from each pier being cut at the crown for its entire transverse width, so that we have on either side of these expansion joints cantilever beams which are reinforced. The centering of the main arches was not struck until these spandrel arches and all of the work above the main arches had been completed up to the bottom of the coping. To permit further of the adjustment of the portion of the masonry above the backs of the main



PART EAST ELEVATION.

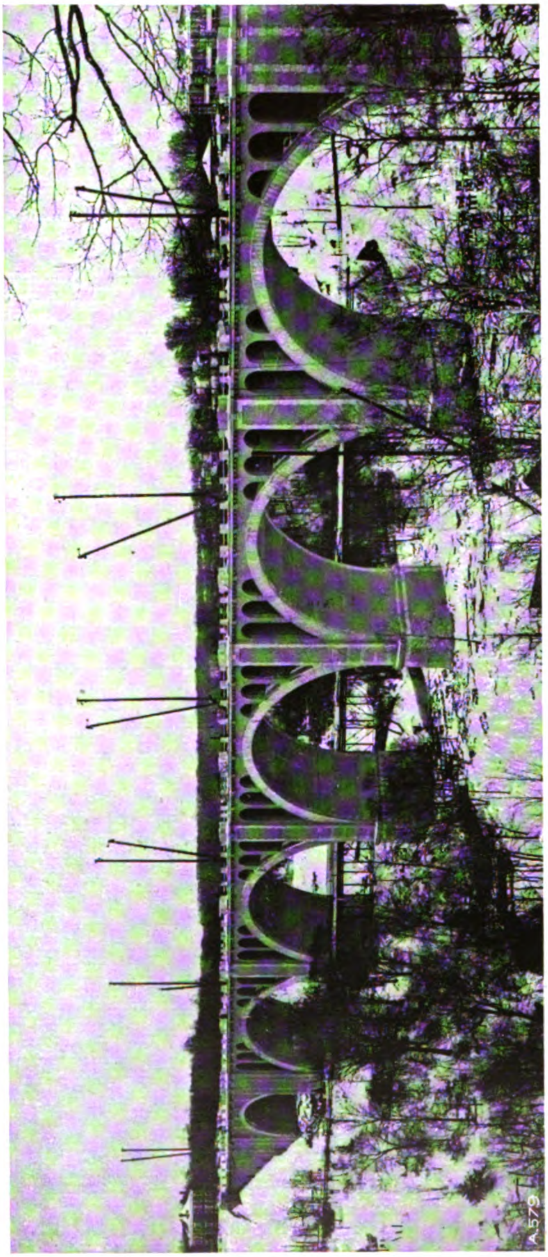


PLAN OF ROADWAY AND SIDEWALK.

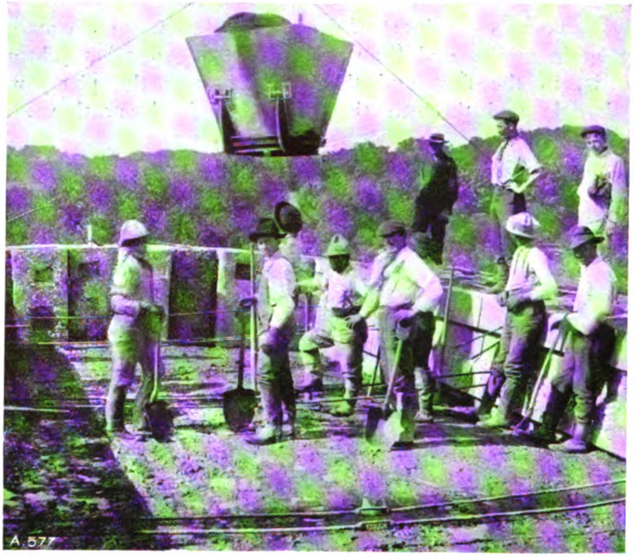
PLAN AT SPRING OF 82 AND 150 FT. ARCHES.

arches, the crown of the middle arch of each set of spandrel arches was not concreted in until the centre of the main arches had been struck. The expansion joints in the spandrel arches—that is, in the first and third arches from the piers—were carried up through the dentals and through the coping, and observation made this year indicated that these joints are about $\frac{1}{8}$ in. larger in winter than they are in summer. The arch-ring stones are not pointed, because it was not desired to bring any more pressure on the edges of these stones or blocks than was absolutely necessary. The main arches were keyed in the early winter and struck in the early summer, and it is thought that this fact made it somewhat easier to strike these main arches, on account of the tendency of the main arches to rise with a rise in temperature. The cost of striking each wedge was between 25 and 30 cents. The cost of the demolition of this centre was about £1 a thousand ft. The contractor received for the old lumber an average of about £2 5s. a thousand ft.

Connecticut Avenue bridge will be finished with a concrete parapet and metal railing of the following general description:—Over the piers there will be a solid parapet and between the piers, every 17 ft., there will be concrete posts, each coming directly over the spandrel walls. Between these concrete posts will be an iron railing, consisting of vertical $1\frac{1}{8}$ in.

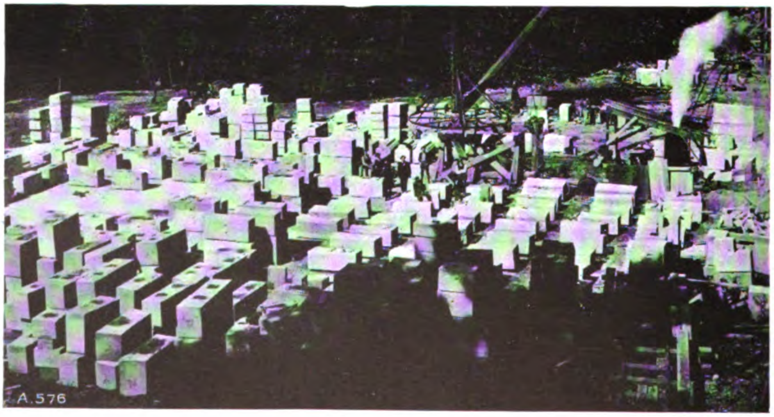


A General View when nearing Completion.

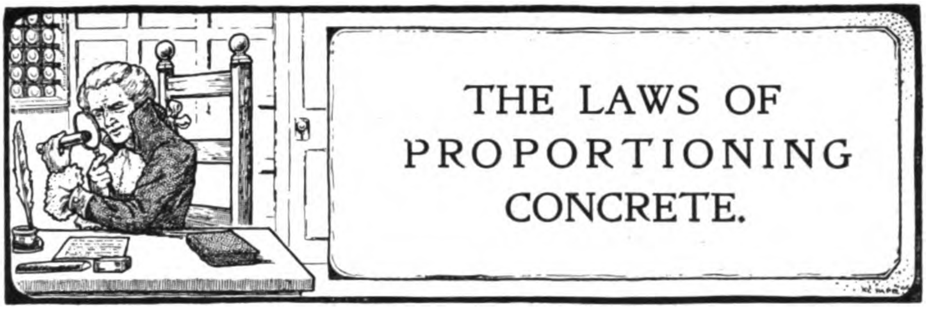


CONCRETING THE SECTIONS.

square balusters and top hand-rail section, having a width of 6 in. (cast-iron). The bottom bar will be $1\frac{1}{4}$ in. by 3 in. Both the bottom bar and hand-rail section are fastened into the concrete posts. The lamps will be of ornamental cast-iron. The bridge will have two sidewalks of 8 ft. and a roadway of 36 ft. The roadway will be temporary, made of macadam, until the entire fill has had an opportunity to settle. The portion of the cement sidewalk which rests directly on the coping will be laid at once, and the balance of the sidewalk which rests on the fill will not be laid in cement, but at present will be laid with macadam, and when the fill has settled it will be laid in cement. At each end of the bridge there will be two lions cast in spelter.



WHERE THE CONCRETE BLOCKS WERE PREPARED.



THE LAWS OF PROPORTIONING CONCRETE.

Summarised and commented upon by Mr. CHARLES F. MARSH, M.Inst.C.E., M.Am.Soc.C.E.,
Author of "Reinforced Concrete."

We publish the following summary by Mr. Charles F. Marsh of this most interesting investigation conducted in the United States.

Whilst the summary speaks for itself, we cannot but congratulate the eminent investigators on the excellence of the work they have carried out, and point to it as a splendid example of the research work which is being carried out in the United States in connection with the application of concrete.

For the full record we must refer our readers to the proceedings of the American Society of Civil Engineers, Vol. XXXIII.—ED.

THE proper proportioning of the mixtures for mortars and concretes was scientifically studied by Mons. Feret, who published the results of his experiments and the conclusions he drew therefrom in the Annales des Pontes et Chaussées during 1892.

Mons. Feret found that the resistance of mortar to compression could be expressed by the equation—

$$P=K\left[\frac{c}{1-(c+s)}\right]^2$$

Where P is the resistance, c and s the absolute volumes of the cement and sand respectively, and K is a co-efficient which varies with the kind of cement used and with the conditions of storage. The above equation shows that the strength of concretes mixed with the same volume of the same kind of cement will increase as $(c+s)$ or as the density of the mixture increases.

It is immaterial, in so far as the density is concerned, if some of the cement is replaced by the same volume of sand of equal fineness.

Mons. Feret has arrived at an approximate formula giving the compressive resistance of a mortar by plotting the values of $\left(\frac{c}{1-s}\right)$ as abscissa and the resistances as ordinates for various experiments. This formula is $P=1{,}965\left(\frac{c}{1-s}\right)$ in millogram centimetre units, or as 1 kilogram per square centimetre equals 14·22 pounds per sq. in., the equation transposed into English equivalents becomes $P=27{,}942\left(\frac{c}{1-s}\right)^2$, or practically $P=28{,}000\left(\frac{c}{1-s}\right)^2$.

With regard to concretes, Mons. Feret found that the same general rules held, and that with the same absolute volume of cement the resistance increases with the density. He found that to obtain the greatest resistance it was advisable to increase as much as possible the size of the broken stone, to diminish the proportion of the fine grains in the mortar by using a rich mortar made with large grained sand and to use the least possible amount of mortar that would thoroughly surround the stone.

Messrs. Taylor and Thompson give a formula for the compressive strength of concrete in their book, "Concrete Plain and Reinforced," of similar form to M. Feret's formula for mortar—

$$P=M\left(\frac{c}{1+c-(s+g)}-0{\cdot}1\right).$$

Where P is the unit compressive strength of the concrete, c = the absolute volume of the cement in a unit volume of concrete, s = the absolute volume of sand in a unit volume of concrete, g = the absolute volume of stone in a unit volume of concrete, M = a co-efficient which is constant for all proportions of the same material mixed and stored under similar conditions, but varies with the texture of the coarse aggregate and the age of the specimen.

They give values of M for broken stone concrete ranging in size from 2 to 2½ in. down to ¼ to ½ in. For the compressive strength in lbs. per sq. in. :—

Age.	Co-efficient
7 days	9,500
1 month	12,500
3 months	15,600
6 months	16,900
1 year	18,000

It will be seen from the above equation that the strength of a concrete increases as $(s+g)$ becomes greater or as the density increases.

The scientific proportioning of concrete has recently been carried a step further by a series of experiments carried out by Messrs. W. B. Fuller and Sanford E. Thompson, from which they have shown that the different sizes of the sand and stone should be proportioned in such a way that if the sizes of the screen are plotted as abscissa and the percentages by weight of the aggregate and cement passing through the various-sized screens as ordinates, the curve should take a form resembling a parabola, being the combination of a curve approaching an ellipse for the sand portion and a tangent straight line for the stone portion, the ellipse running to a diameter of $\frac{1}{10}$th the diameter of the maximum size of stone, and the stone from this point being uniformly graded.

Messrs. Fuller and Thompson presented a paper on The Laws of Proportioning Concrete before the American Society of Civil Engineers on April 17th, 1907,* describing their experiments and the conclusions deduced therefrom.

This paper and the discussion upon it, published in Volume XXXIII., Nos. 3 and 5, are most interesting and instructive, and the whole subject of scientific proportioning is very fully dealt with. The strength, permeability, and elasticity of properly-graded concretes were discussed and many curves and tables were given which, with the letterpress, cover many pages. It is, therefore, only possible to give the merest outline of the paper, and for a further study of the subject the reader must be referred to the numbers of the "Proceedings" given above. The authors of the paper state that the objects of mechanical analysis curves, as applied to concrete aggregates are :—

(1) To show graphically the sizes and relative quantities of the particles.

(2) To indicate what sized particles are needed to make the aggregate more nearly perfect, and so enable the engineer to improve it by the addition or substitution of another material.

(3) To afford means for determining the best proportions of different aggregates.

Messrs. Fuller and Thompson state that mechanical analysis consists in separating the particles or grains of a sample of any material into the various sizes of which it is composed, so that the material may be represented by a curve, each ordinate of which is the percentage of the weight of the total sample which passes a sieve having holes of a diameter represented by the distance of this ordinate from the origin of the diagram.

---

* Proceedings of the American Society of Civil Engineers. Vol. XXXIII. No. 3. Page 222.

For the purpose of the experiments the aggregates were screened through screens of twenty-one different sizes. The materials tested were crushed mica schist rock used for Jerome Park reservoir and gravel dredged from the river at Cowe Bay.

The mechanical analysis of the two materials is given in Table I.

TABLE I.

Diameter of opening in sieves, in inches.	Jerome Park Material.				Cowe Bay Sand and Stone.			
	2¼-in. stone, percentage passing.	1-in. stone, percentage passing.	½-in. stone, percentage passing.	Screenings, percentage passing.	2¼-in. stone, percentage passing.	1-in. stone, percentage passing.	½-in. stone, percentage passing.	Sand, percentage passing.
2.25	100.0	....	....	....	100.0	....	....	100.00
1.50	78.4	....	....	....	94.2	....	....	100.00
1.00	41.8	100.0	....	....	81.8	100.00	....	100.00
0.75	29.9	71.5	....	....	67.3	82.27	....	100.00
0.60	18.4	44.2	....	100.0	44.8	54.77	....	97.9
0.48	11.4	27.3	100.0	99.7	26.4	32.28	100.00	96.2
0.36	6.8	16.3	59.6	99.1	14.0	17.12	53.03	95.0
0.29	3.6	8.6	31.6	96.9	8.6	10.51	32.57	93.7
0.20	1.9	4.5	16.7	92.8	5.05	6.17	19.13	91.8
1.16	1.3	3.1	11.4	87.2	3.40	4.16	12.88	88.9
0.10	1.0	2.4	8.7	80.7	1.76	2.15	6.67	85.1
0.075	0.67	1.6	5.8	76.7	1.57	1.92	5.95	78.9
0.046	0.61	1.4	5.3	70.8	1.38	1.69	5.23	68.3
0.034	0.58	1.39	5.0	66.3	1.28	1.56	4.85	62.4
0.020	0.55	1.32	4.8	55.8	1.09	1.33	4.13	49.9
0.016	0.48	1.15	4.2	47.8	0.98	1.20	3.71	37.3
0.014	0.47	1.12	4.1	43.2	0.80	0.98	3.03	31.8
0.0071	0.32	0.76	2.8	21.0	0.47	0.57	1.78	7.1
0.0058	0.27	0.64	2.3	15.4	0.43	0.53	1.63	4.6
0.0036	0.19	0.45	1.6	6.7	0.26	0.32	0.98	2.3
0.0027	0.01	0.24	0.8	2.3	0.01	0.01	0.04	1.3

As a preliminary to the resistance experiments, nearly 400 trial mixes of aggregates, composed of various-sized particles, following a logical plan, and containing first 10 per cent. of cement to the total weight of the dry materials and then other percentages of cement were made and mixed with water to the same medium wet consistency, and the resulting volumes thus obtained from exactly the same total weight of dry materials were compared.

It was impossible to select a definite percentage of water for mixing because of the variation in size of the grains, and the water was, therefore, added by judgment to obtain a soft mushy mixture, and as the concrete was rammed the surplus water rose to the surface and was removed by a small pump.

The form used for recording the data in these tests is given in Table 2. All the numbers not in italics refer to the numbers of the various items: for instance, the fraction following Item 19 represents the portion of water in the mix adhering to the tray and tools, and is really—

$$\text{Item } 19 = \frac{\text{Item } 14}{\text{Item } 5 + \text{Item } 6 + \text{Item } 10} \times \text{Item } 10.$$

TABLE 2.—FORM FOR RECORDING VOLUMETRIC TESTS.

1.	No.	*377½*	24.	Depth of concrete in Cylinder, in.	*5.99*
2.	Date	*3/10/05*	25.	Vol. of concrete in Cylinder, in., *0.0293* × *24* —*0.001*	*0.174*
3.	Nominal Mix		26.	Net Water per cu. ft. as mixed $\frac{10}{25}$	*9.2*
4.	Kind of Cement	*Giant No. 20*	27.	" " " " " " set $\frac{20}{25}$	*9.1*
5.	Weight...	*2.65*	28.	" Cement " " " " $\frac{21}{25}$	*15.0*
6.	Wt. of Aggreg. finer than *0.0071*	*0.85*	29.	" Aggreg. " " " " $\frac{22+23}{25}$	*128.4*
7.	" " " coarser " "	*21.50*	30.	Abs. Vol. Water per cu. ft. as set $\frac{27}{62.4}$	*0.116*
8.	" " Vessel + Water (1)...	*29.00*	31.	" " Cement " " " " " " $\frac{28}{191}$	*0.077*
9.	" " " " (2)...	*27.40*	32.	" " Aggreg. " " " " " " $\frac{29}{165}$	*0.778*
10.	" " Water used...	*1.60*	33.	" " Total 30+31+32	*1.001*
11.	Total Wt. Mixed	*26.00*	34.	Wt. of Form + Concrete...	*77.23*
12.	Wt. of Tray + Tools (2)	*13.15*	35.	" " Form	*50.75*
13.	" " " " (1)	*1 .08*	36.	" " Concrete	*26.48*
14.	" " Mixed Adhering...	*0.07*	37.		
15.	" Syringe + Water	*2.62*	38.	Temp. of Water	*40°*
16.	" Syringe...	*2.60*	39.	Time of Mixing after Wetting...	
17.	" Free Water	*0.02*	40.	Remarks on Consistency...	
18.	Net Mix Set = 11—14—17	*26.51*			
19.	Water left on Tray $\frac{10 \times 14}{5+6+10}$	*0.02*			
20.	Net Water Set = 10—17—19	*1.58*			
21.	Net Cement " = $\frac{5 \times 14}{5+6+10}$	*2.61*			
22	" Aggreg. finer than *0.0071* = $6 \times \frac{6 \times 14}{6+6+10}$	*0.84*			
23.	Net Aggreg. coarser than *0.0071*	*21.50*			

REMARKS.—*Looked little stony in mix. Top surface filled. No excess of mortar on top. Small stones. No* 10 *right under top surface.*

The volumetric tests were undertaken for the purpose of determining, for the various materials under consideration, artificial mixtures of aggregates, of diameters graded by methods of mechanical analysis, which would give the maximum density. These ideal mixtures having been determined, the concrete made from them could be compared with respect to density, strength and permiability, with concrete made from simple mixtures of natural materials, and thus the best proportions to use with different materials upon actual construction work could be fixed.

Most of the experiments were made upon concretes having 10 per cent. of cement to the total volume of the aggregates.

As the necessity of using cement in the tests for density might be questioned for the reason that it would appear at first sight that it would be simpler to use only dry aggregates, Messrs. Fuller and Thompson, in their paper, point out that, as a matter of fact, both theory and experiment prove that mixtures of aggregates which give the greatest density when dry do not necessarily give the greatest density when mixed with the cement and water. The cement and water actually occupy space in the mass, as many of the voids are too small for the grains of cement or fine sand to fit into them *without expanding the volume*, and the water surrounds the grains of fine sand and cement, and actually increases the bulk. They instance, as an illustration of this fact, that whereas a cubic foot of fine or very coarse sand when absolutely dry will weigh almost exactly the same; if the two sands are mixed with cement and water the resulting mortar made with the fine sand will occupy a bulk approximately 20 per cent. greater than that made with the coarse-grained sand.

If, for the density tests, fine aggregate, having grains of the same size as cement, were used the aggregate could be mixed with water without using any cement, but such fine aggregate would be more costly than cement because of the labour required to screen it.

In all the density tests for obtaining the mechanical analysis curves the cement was included, since the grains of cement acted similarly to grains of sand of similar size as far as the density was concerned.

A trial curve was drawn and a volumetric test made to determine the density. The curve was then altered in various ways by raising and lowering it different diameters of aggregate, and volumetric tests were made with each experimental curve.

The curve which was found to give the best results consisted of an ellipse for the lower or sand portion, and beyond this a tangential straight line running to the maximum diameter of the stone. The elliptical curve terminated at a diameter of aggregate of about $\frac{1}{10}$th that of the maximum diameter tested.

The curves started below measurable diameters on the 7 per cent. line, indicating that at least 7 per cent. by weight of the very finest diameters of particles of cement or sand, or both,was required for a dense mixture.

Tests were made with maximum sizes of 2¼-in., 1-in. and ½-in. Jerome Park stone, and the curves in each case were similar. It was, however, found that the shape of the curve was not exactly the same for the different sizes, but by introducing a small constant in the values of the axes of the ellipses, an equation was found which fitted all the diameters. Tests were also made with concretes of Cowe Bay shingle and sand and cement, and with Jerome Park broken stone and Cowe Bay sand and cement, the curves in all cases being of a similar character.

The character of the best or ideal sand did not depend upon the shape of the coarse aggregate, the best sand for Jerome Park broken stone being found also the best of the Cowe Bay shingle of the same size, although a less quantity was required with the latter. On the other hand, the curve for the Jerome Park screenings (plus cement) was slightly different from the curve for Cowe Bay sand (plus cement), showing a different arrangement of grains.

EQUATIONS OF IDEAL MECHANICAL ANALYSIS CURVES OF DENSITY.

The curves for the best analysis having been found by trial, mathematical curves were fitted to them for convenience in plotting.

The curves start upon, and are tangent to, the vertical zero axis of percentages at 7 per cent.—that is, at least 7 per cent. of aggregate *plus cement* is finer than No. 200 sieve—and run as ellipses with axes differing slightly with the character of the materials to a point on the vertical ordinate or diameter, the value of which is about $\frac{1}{10}$th the diameter of the maximum-sized stone, and thence by a tangent to the ordinate of maximum diameter intersecting this on the 100 per cent. abscissa.

for practical working conditions, the equations—

$$y=\frac{b}{a}\sqrt{a-x}.$$

Where a and b are the semi-major and the semi-minor axis respectively, this portion of the curve must be plotted from the intersection of the major and minor axes or at a distance of (a) along the horizontal from the zero point of the diagram. Using zero co-ordinates on the mechanical analysis diagram, Messrs. Fuller and Thompson give, for practical working conditions the equations—

$$y=\frac{b}{a}\sqrt{(2ax-x^2)+7}$$

for the curved portion, and for the straight line portion—

$$y=\frac{100-y_1}{\mathrm{D}-x_1}(x-x_1)+y_1$$

where y and x_1 are the co-ordinates at the termination of the elliptical portion of the curve, and D is the maximum diameter of the stone in inches.

The ideal values of *a* and *b* found for the several hundreds of aggregates tested were—

MATERIALS.	a	b
Jerome Park stone and screenings	0·035+0·14	29·4+2·2
Cowe Bay shingle and sand	0·04+0·16	25·4+1·3
Jerome Park stone and Cowe Bay sand ...	0·04+0·16	28·5+1·3

D = the maximum diameter of the stone in inches.

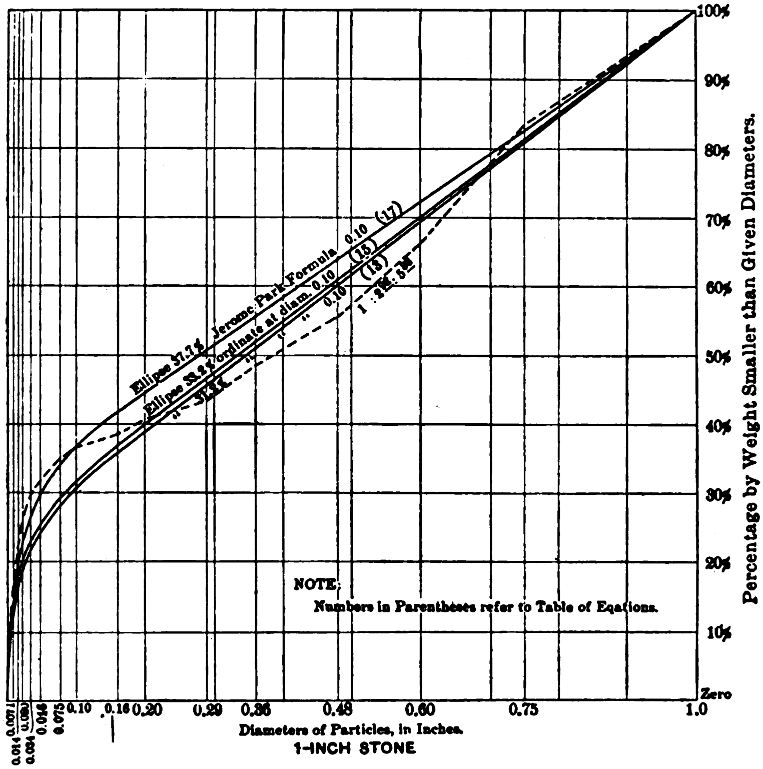
These values are those obtained by small laboratory specimens, thoroughly mixed and carefully placed and compacted; for working conditions they must be modified by increasing the value of *b* and thus adding more sand. This is effected by increasing the value of the constant in the expressions giving the values *b*. It was found necessary to raise all the curves about 2 per cent. at the tangent point to prevent a rough surface, which indicates that there was not sufficient mortar to fill the voids in the stone.

Curve number (see diagram).	GENERAL VALUES.		NUMERICAL VALUES.						Remarks.
			D=2¼		*D*=1		*D*=½		
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	
JEROME PARK SCREENINGS AND STONE GRADED TO ELLIPSE AND TANGENT STRAIGHT LINE.									
(1)	0.035+0.14 *D*	29.4+2.2 *D*	0.35	(34)	0.175	(32)	0.105	(30)	Ideal curve.
(2)	0.035+0.14 *D*	27.4+2.2 *D*	0.35	(32)	....	....	0.105	(32)	
(3)	0.035+0.14 *D*	31.4+2.2 *D*	0.35	(36)	0.175	(34)	0.105	(34)	
(4)	0.035+0.14 *D*	33.4+2.2 *D*	0.35	(38)	....	....	....	....	
COWE BAY SAND AND STONE GRADED TO ELLIPSE AND TANGENT STRAIGHT LINE.									
(9)	0.04 +0.16 *D*	26.4+1.3 *D*	0.40	(29)	0.20	(28)	0.12	27	Ideal Curve.
(10)	0.035+0.14 *D*	29.4+2.2 *D*	0.35	(34)	....	....	....	....	Like Curve (1)
(11)	0.035+0.14 *D*	31.4+2.2 *D*	....	....	0.75	(34)	....	....	Like Curve (3)
JEROME PARK SCREENINGS AND COWE BAY STONE GRADED TO ELLIPSE AND STRAIGHT LINE.									
(12)	0.04+0.16 *D*	28.5+1.3 *D*	0.40	(31)	0.20	(30)	0.12	29	Ideal curve
(13)	0.04+0.16 *D*	26.5+1.3 *D*	....	(28)	0.20	(28)	....	....	
(14)	0.04+0.16 *D*	25.5+1.3 *D*	0.40	....	....	....	....	....	
(15)	0.04+0.16 *D*	27.5+1.3 *D*	0.40	(30)	0.20	(29)	0.12	28	
(16)	0.035+0.14 *D*	29.4+2.2 *D*	0.35	(34)	....	....	....	....	Like curve (1)
(17)	0.035+0.14 *D*	31.4+2.2 *D*	....	....	0.175	(34)	....	....	Like curve (3)

and *Fig.* 1 shows a typical mechanical analysis diagram for 1-in. maximum-sized stone.

The mixture shown as $1 : 2^{92} : 5^{88}$ is really 1 : 2·92 : 5·88.

The diagram indicates the advisability of increasing the proportion of stone up to 0·75 in. diameter.



Mechanical Analysis of Mixtures of Cement, Cowe Bay Sand, and Jerome Park Stone of 1 in. Maximum Diameter.

Permeability Tests.

These tests indicated in general that, using different proportions and different sizes of the same class of materials, the laws of watertightness are somewhat similar to those of strength. If the percentages of cement are the same, the specimens having the greater density are usually the most watertight, and in specimens of the same density but with different percentages of cement, the watertightness increases with the percentages of cement. The ratios, however, are very different from the ratios of either density or strength, a slight difference in the composition producing a great effect upon the watertightness.

Different kinds of aggregates, also for reasons not yet explained, produce very different results in watertightness.

Table 4 gives the data of the permeability tests. The apparatus used for conducting these tests was very ingenious, and ensured the water forcing its way through the whole length of the specimen, and the pressure being applied over the entire upper surface of the specimen. The length of the specimen was about 17 inches.

TABLE 4.—PERMEABILITY OF 6×6×17-IN. CONCRETE
PORTLAND CEMENT

(1) Reference Numbers.	(2) Proportion, by Weight.	(3) Percentage of Cement to total dry material.	(4) Kind of Stone.	(5) Kind of Sand.	(6) Maximum size of stone, in inches.	(7) Uniformly graded above given diameter, in inches.	(8) Percentage finer than diameter in Column 7*.	(9) Curve below diameter in Column 7.
155	1:9	10	J. P.	J. P.	2¼	0.20	37.80	Ellipse
151	1:9	10	,,	,,	1	0.10	35.90	,,
165	1:9	10	,,	,,	½	0.075	36.30	,,
168	1:2½:6½	10	,,	,,	2¼	....	....	....
167	1:3:6	10	,,	,,	2¼	....	....	....
172 B	1:2½:6½	10	,,	,,	1	....	....	....
170	1:3:6	10	,,	,,	1	....	....	....
192 B	1:2½:6½	10	,,	,,	½	....	....	....
176 B	1:3:6	10	,,	,,	½	....	....	....
187 A	1:9 uniform stone	10	,,	,,	2½	0.20	37.8	Ellipse
193 C	1:11.5	8	,,	,,	2¼	0.20	37.8	,,
179 B	1:7	12.5	,,	,,	2¼	0.20	37.8	,,
183 B	1:5¾	15	,,	,,	2¼	0.20	37.8	,,
217	1:8:4	10.6	C. B.	C. B.	2¼	0.20	32.1	,,
221	1:2.91:5.62	10.6	,,	,,	2¼	....	....	....
234	1:8:4	10.6	,,	,,	2¼	0.20	37.8	Ellipse
227	1:2.91:5.62	10.6	,,	,,	1	....	....	....
233	1:10.8	8.5	,,	,,	2¼	0.20	32.1	Ellipse
224	1:6.5	13.75	,,	,,	2¼	0.20	32.1	,,
225	1:5.3	15.9	,,	,,	2¼	0.20	32.1	,,
213 C	1:8.8	10.2	J. P.	,,	2¼	0.20	33·8	,,
219 B	1:8.8	10.2	,,	,,	2¼	0.20	37·8	,,
205	1:2.92:5.88	10.2	,,	,,	2¼	....	....	....
203 C	1:2.92:5.88	10.2	,,	,,	1	....	....	....
207 C	1:2.92:5.88	10.2	,,	,,	½	....	....	....
218	1:6.88	12.75	,,	,,	2¼	0.20	33·8	Ellipse
216	1:5.54	15.3	,,	,,	2¼	0.20	33·8	,,

* Including cement.

In Cowe Bay mixtures the percentage of cement by weight is increased in each case to balance the

J.P. = Jerome Park ; C.B. = Cowe Bay.

PRISMS, MADE OF VARIOUS AGGREGATE AND GIANT
AGE, 3½ MONTHS.

(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
Calculated Volume in Cubic Feet of Material in 1 Cubic Foot of Concrete, as Made.						Age, in days.	Time in which water appears, in minutes.	Rate of Flow of Water in Grammes per Minute.			
Cement.	Aggregate.	Total dry.	Water.	Total voids.	Total calculated volume.			At 20 lb. per sq. in.	At 40 lb. per sq. in.	At 60 lb. per sq. in.	At 80 lb. per sq. in.
0.078	0.777	0.855	0.173	0.145	1.028	110	3	11.2	24.4	36.9	48.7
0.075	0.745	0.820	0.191	0.180	1.011	112	21	0	11.6	21.6	35.1
0.070	0.700	0.770	0.208	0.230	0.978	112	29	0	....	20	36
0.076	0.758	0.834	0.154	0.166	0.988	119	20	0	3	8	12
0.074	0.738	0.812	0.144	0.188	0.956	113	3	15	27	46	....
0.074	0.736	0.810	0.232	0.190	1.042	105	3.5	25	87	153	....
0.070	0.730	0.802	0.226	0.198	1.028	119	7	8	18	31	49
0.070	0.703	0.773	0.224	0.227	0.997	137	25	0	13	35	63
0.070	0.702	0.772	0.199	0.228	0.971	101	24	0	19	34	50
0.077	0.775	0.852	0.154	0.148	1.006	119	3.75	14	21	27	33
0.060	0.771	0.831	0.170	0.169	1.001	140	7	25	161	237	273
0.037	0.755	0.852	0.189	0.148	1.041	107	3	15	22	30	38
0.130	0.715	0.845	0.186	0.155	1.031	105	5.5	5	8	10	12
0.079	0.776	0.855	0.133	0.145	0.988	146	17	1	3	5	6
0.076	0.750	0.826	0.157	0.174	0.983	133	134	0	0	0	0.7
0.079	0.781	0.860	0.147	0.140	1.007	147	72	0	0	1.9	3.9
0.077	0.755	0.832	0.173	0.168	1.005	150	125	0	0	0	1.8
0.064	0.807	0.871	0.154	0.129	1.025	147	3	14.7	25	37.6	42.7
0.100	0.765	0.865	0.149	0.135	1.014	151	100	0	0	0	0.5
0.129	0.738	0.867	0.147	0.133	1.014	151	98	0	0	0	1.4
0.080	0.793	0.873	0.152	0.127	1.025	137	8.75	4	11	17	22
0.078	0.772	0.850	0.160	0.150	1.010	116	45.5	0	1	2	3
0.075	0.740	0.815	0.160	0.185	0.975	132	7	1	4	8	12
0.075	0.745	0.820	0.156	0.180	0.976	132	26	0	5	10	15
0.070	0.703	0.773	0.195	0.227	0.968	132	29	0	10	17	25
0.099	0.767	0.867	0.151	0.133	1.017	148	10.5	2	2	3	3
0.117	0.735	0.852	0.154	0.148	1.006	147	....	0	0	0.7	1.4

difference in specific gravity between this and the Jerome Park material.

The effect of the maximum size of the stone upon the permeability is shown in *Table* 5.

TABLE 5.—EFFECT OF SIZE OF STONE ON PERMEABILITY OF CONCRETE SPECIMENS.

No. of Beam.	Proportion by Weight.	Percentage of cement to total dry material.	Kind of Aggregate. Stone.	Kind of Aggregate. Sand.	Maximum size of stone, in inches.	Time in which water appears, in minutes.	Rate of Flow of Water in Grammes per Minute at the Following Pressures per Square Inch. 20 lb.	40 lb.	60 lb.	80 lb.
155	1:9	10	J. P.	J. P.	2¼	3	11	24	369	49
151	:9	10	,,	,,	1	21	0	12	22	35
165	1:9	10	,,	,,	½	29	0	...	20	36
168	$1:2^5:6^5$	10	J. P.	J. P.	2¼	20	0	3	8	12
172	$1:2^5:6^5$	10	,,	,,	1	3.5	25	87	153	...
192	$1:2^5:6^5$	10	,,	,,	½	2.5	0	13	35	63
167	1:3:6	10	J. P.	J. P.	2¼	3	15	27	46	...
170	1:3:6	10	,,	,,	1	7	8	18	31	49
176	1:3:6	10	,,	,,	½	24	0	19	34	50
221	$1:2^{91}:5^{62}$	10.6	C. B.	C. B.	2¼	134	0	0	0	0.7
227	$1:2^{91}:5^{62}$	10.6	,,	,,	1	125	0	0	0	1.8
205	$1:2^{92}:5^{68}$	10.2	J. P.	C. B.	2¼	7	1	4	8	12
203	$1:2^{92}:5^{68}$	10.2	,,	,,	1	26	0	5	10	15
207	$1:2^{92}.5^{68}$	10.2	,,	,,	½	29	0	10	17	20

J. P. = Jerome Park; C. B. = Cowe Bay.

Table 6 shows the effect of a reduction in the length of the specimen on the permeability.

TABLE 6.—COMPARATIVE PERMEABILITY OF CONCRETE THROUGH A LENGTH OF 8.5 INCHES *vs.* A LENGTH OF 17 INCHES. SPECIMEN NO. 224. COWE BAY AGGREGATES. PROPORTIONS, 1 : 6.5 (BY WEIGHT). AVERAGE AGE, 153 DAYS.

(1)	(2)	(3)	(4)	(5)
Pressure in pounds per square inch.	Rate of Flow, in Grammes per Minute. 8.5×5.95×6.05-in. specimens. (1)	(2)	Average.	17×5.95×6.15-in. specimen.
20	0.16	0.47	0.32	0
40	0.87	1.49	1.18	0
60	1.40	2.58	1.99	0
80	2.17	3.93	3.05	0.47

The conclusions which Messrs. Fuller and Thompson draw from their experiments are given below :—

Unless otherwise designated, the percentage of cement and the relative grading of the aggregates remain the same.

1.—Stone of the largest size makes the strongest concrete under both compression and transverse loading, *i.e.*, a graded aggregate in which the maximum size of the stone is 2¼ in. in diameter gives stronger concrete than a graded aggregate with 1-in. maximum size, and the 1-in. stone gives a stronger concrete than ½-in. stone. A concrete in which the graded aggregate runs to 1 in. in maximum size will require for equal strength about one-sixth more cement, and with an aggregate running to ½ in. maximum size about one-third more cement than concrete with an aggregate in which the maximum size is 2¼ in.

2.—The largest stone makes the densest concrete. Concrete made with graded stone having a maximum diameter of 2¼ in. is noticeably denser than that with 1-in. stone, and this is denser than that with ½-in. stone.

3.—Round material like gravel, under similar conditions, gives a denser concrete than broken stone.

4.—Sand produces a denser concrete than screenings of similar sized grains.

5.—A concrete with an angular coarse aggregate, such as broken stone, is stronger than one with a rounded coarse aggregate, like gravel, and the same sand and cement—although the rounded aggregates produces greater density—thus indicating a stronger adhesion of cement to broken stone than to gravel. However, if the sand is also angular, like screenings, but with its grains of the same sizes as the sand, the concrete with rounded coarse and fine aggregate is the stronger, probably because of its greater density.

6.—Aggregates in which particles have been specially graded in sizes so as to give, when water and cement are added, an artificial mixture of greatest density, produce concrete of higher strength than mixtures of cement and natural materials in similar proportions. The average improvement in strength by artificial grading under the conditions of the tests was about 14 per cent. Comparing the tests of strength of concrete having different percentages of cement, it is found that for similar strength the best artificially graded aggregate would require about 12 per cent. less cement than like mixtures of natural materials.

7.—The strength and density of concrete is affected but slightly, if at all, by decreasing the quantity of the medium size stone of the aggregate and increasing the quantity of the coarsest stone. An excess of stone of medium size, on the other hand, appreciably decreases the density and strength of the concrete.

8.—The strength and density of concrete is affected by the variation in the diameter of the particles of sand more than by variation in the diameters of the stone particles.

9.—An excess of fine or of medium sand decreases the density and also the strength of the concrete, as will also a deficiency of fine grains of sand in a lean concrete.

10.—The substitution of cement for fine sand does not affect the density of the mixture, but increases the strength, although in a slightly smaller ratio than the increase in the ratio of cement.

11.—It follows from the foregoing conclusions that the correct proportioning of concrete for strength consists in finding, with any percentage of cement, a concrete mixture of maximum density, and increasing or decreasing the cement by substituting it for the fine particles in the sand or *vice versa*.

12.—In ordinary proportioning with a given sand and stone and a given percentage of cement, the densest and strongest mixture is attained when the volume of the mixture of sand, cement and water is so small as just to fill the voids in the stone. In other words, in practical construction, use as small a proportion of sand and as large a proportion of stone as is possible without producing visible voids in the concrete. NOTE.—Table 7 shows the effect of increasing the percentage of sand and decreasing that of the stone in mixtures having the same proportion by weight of cement to the total aggregate.

TABLE 7.—EFFECT OF INCREASING THE PERCENTAGE OF SAND AND DECREASING THE STONE.

Proportion by weight of cement to total aggregate.		Absolute volume of cement.	Density—*i.e.*, total cement + sand + stone.	Average modulus of rupture at 33 days in pounds per sq. in.
1:8	1:2:6	0.091	0.865	319
1:8	1.3:5	0.086	0.833	285
1:8	1:4:4	0.082	0.801	209
1:8	1:5:3	0.080	0.799	151
1:8	1:6:2	0.076	0.760	102
1:8	1:8:0	0.073	0.754	41

13.—The best mixture of cement and aggregate has a mechanical analysis curve resembling a parabola, which is a combination of a curve approaching an ellipse for the sand portion and a tangent straight line for the stone portion. The ellipse runs to a diameter of one-tenth of the diameter of the maximum size of stone, and the stone from this point is uniformly graded.

14.—The ideal mechanical analysis curve, *i.e.*, the best curve, is slightly different for different materials. Cowe Bay sand and gravel, for example, pack closer than Jerome Park stone and screenings, and therefore require less of the size of grain which the writers designate as sand.

15.—The form of the best analysis curve for any given material is nearly the same for all sizes of stone—that is, the curve for ½-in., 1-in., and 2¼-in. maximum stone may be described by an equation with the maximum diameter as the only variable. In other words, suppose a diagram in which the left ordinate is zero, and the extreme right ordinate corresponds to 2¼-in. stone, with the best curve for this stone drawn upon it. If, now, on this diagram the vertical scale remains the same, but the horizontal scale is increased two and a quarter times, so that the diameter of 1-in. stone corresponds to the extreme right-hand ordinate, the best curve for the 1-in. stone will be very nearly the one already drawn for the 2¼-in. stone. The chief difference between the two is that the larger size of stone requires a slightly higher curve in the fine sand portion.

16.—It follows from this last conclusion that, from a scientific standpoint, the term "sand" is a relative one. With 2¼-in. stone, the best sand would range in size from 0 to 0·22 in. in diameter, while the best sand for ½-in. stone would range in size from 0 to 0·05 in. in diameter.

17.—The permeability or flow of water through concrete is less as the percentage of cement is increased, and in very much larger inverse ratio.

18.—The permeability is less as the maximum size of the stone is greater. Concrete with maximum size stone of 2¼-in. diameter is, in general, less permeable than that with 1-in. maximum diameter stone, and this is less permeable than that with ½-in. stone.

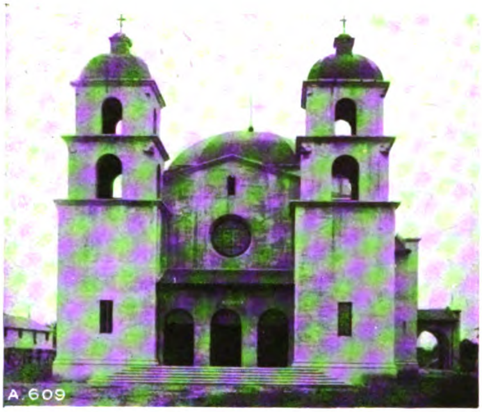
19.—Concrete of cement, sand and gravel is less permeable than concrete of cement, screenings and broken stone; that is, for equal permeability, a slightly smaller quantity of cement is required with rounded aggregates like gravel than with sharp aggregates like broken stone.

20.—Concrete of mixed broken stone, sand and cement is more permeable than concrete of gravel, sand and cement, and less permeable than similar concrete of broken stone, screenings and cement; that is, for water-tightness, less cement is required with rounded sand and gravel than with broken stone and screenings.

21.—The permeability decreases materially with age; increases nearly uniformly with the increase in pressure; and increases as the thickness of the concrete decreases, but in a much larger inverse ratio.

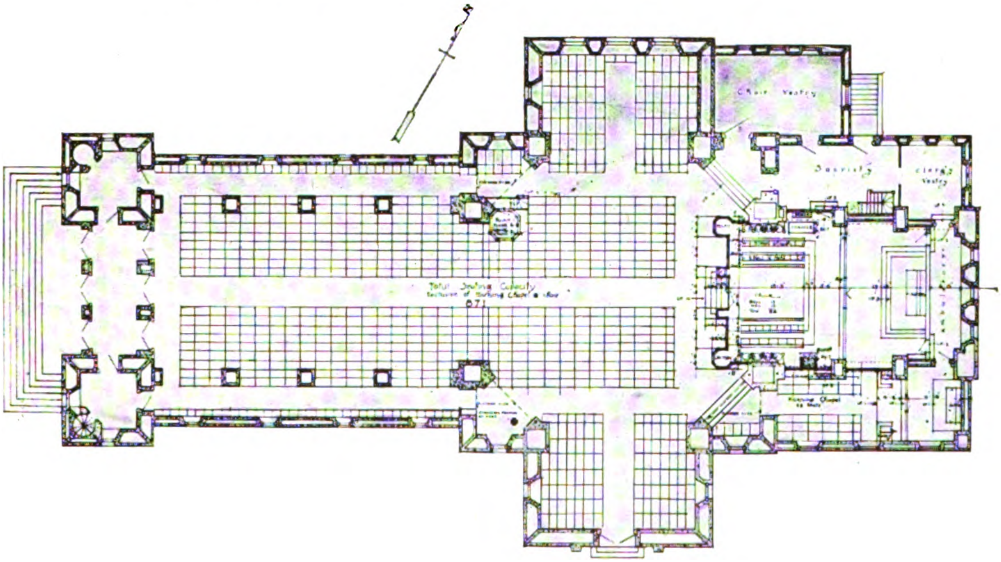
A Reinforced Concrete Cathedral in Manila

(Philippine Islands)

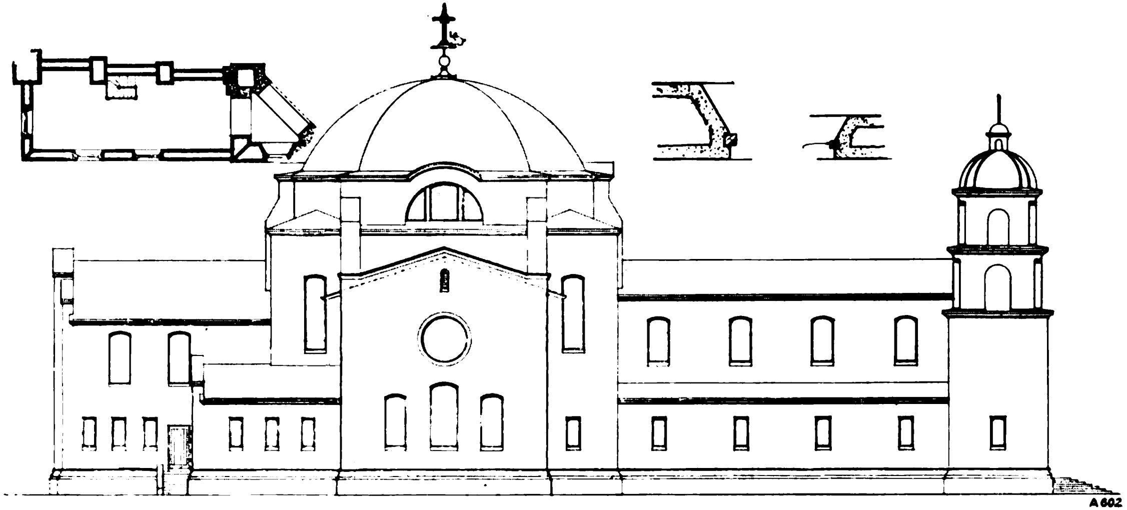


In our last issue we published a description of the Concrete Domes of the Westminster Cathedral, which were constructed of plain concrete, i.e., not reinforced with metal. We have now pleasure in presenting a short description of the Episcopal Cathedral of St. Mary and St. John, designed by an American firm of architects, and constructed of reinforced concrete in Manila, Philippine Islands. This example should be of particular interest to such of our readers as have to supervise or execute work in tropical climates, and in districts subject to earthquake shock.—ED.

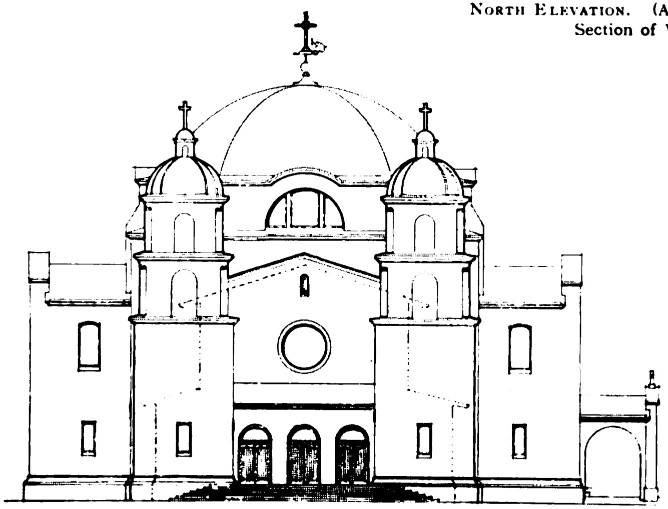
THE reinforced concrete cathedral of St. Mary and St. John, which has recently been built in Manila, Philippine Islands, is one more striking example of the adaptability of this form of construction. In all tropical countries, where the destructive agencies of white ants and dry-rot have to be reckoned with, and also the liability of the building having to withstand earthquake shock, reinforced concrete is certainly one of the most suitable materials that could be adopted.



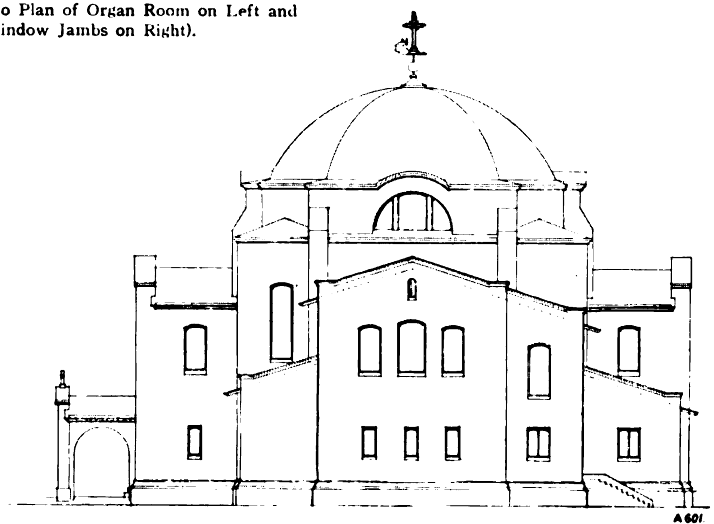
PLAN OF THE REINFORCED CONCRETE CATHEDRAL OF ST. JOHN AND ST MARY, MANILA (PHILIPPINE ISLANDS).



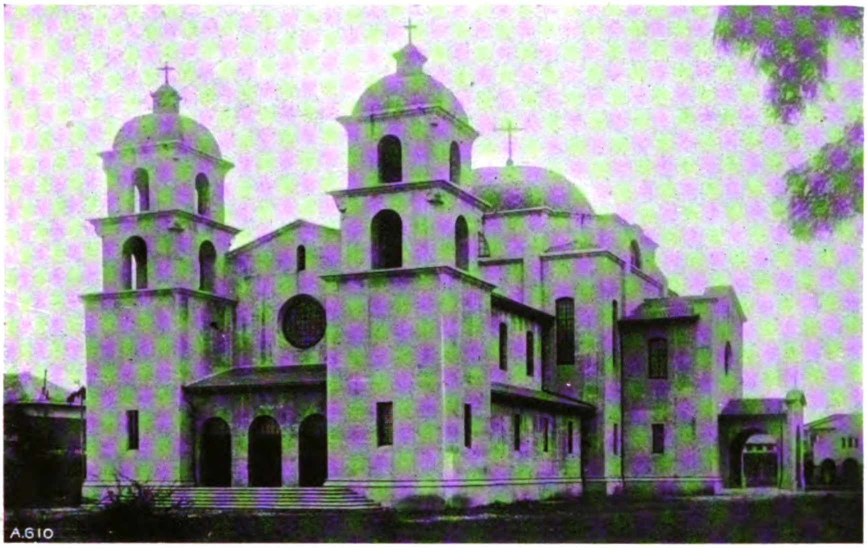
NORTH ELEVATION. (Also Plan of Organ Room on Left and Section of Window Jambs on Right).



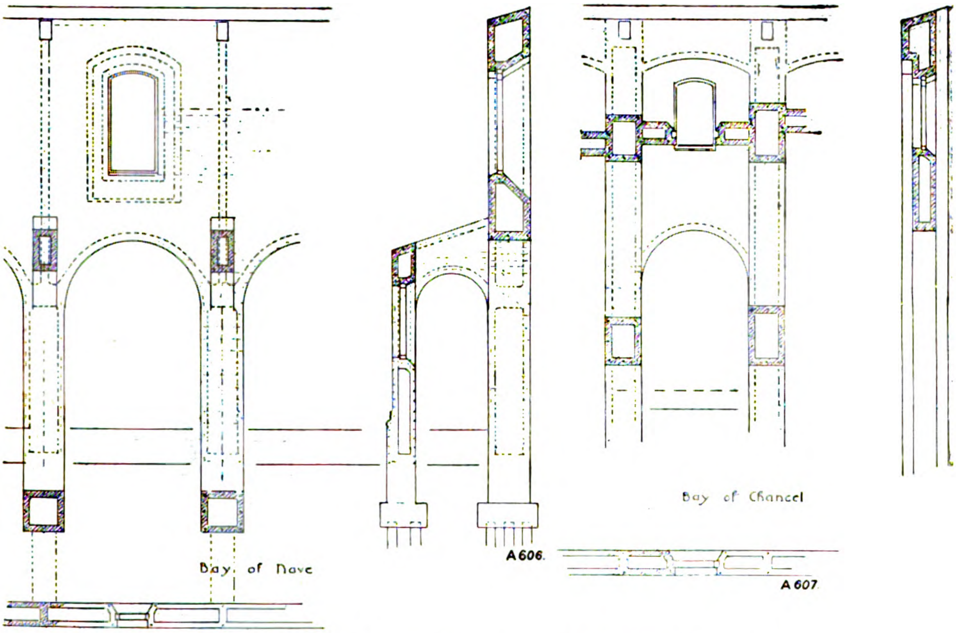
WEST ELEVATION.



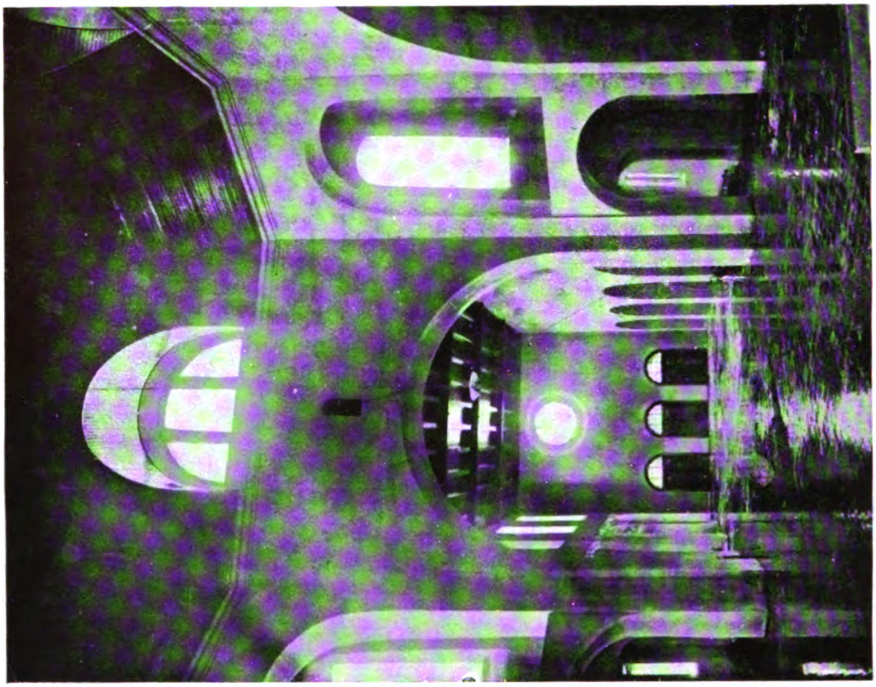
EAST ELEVATION.



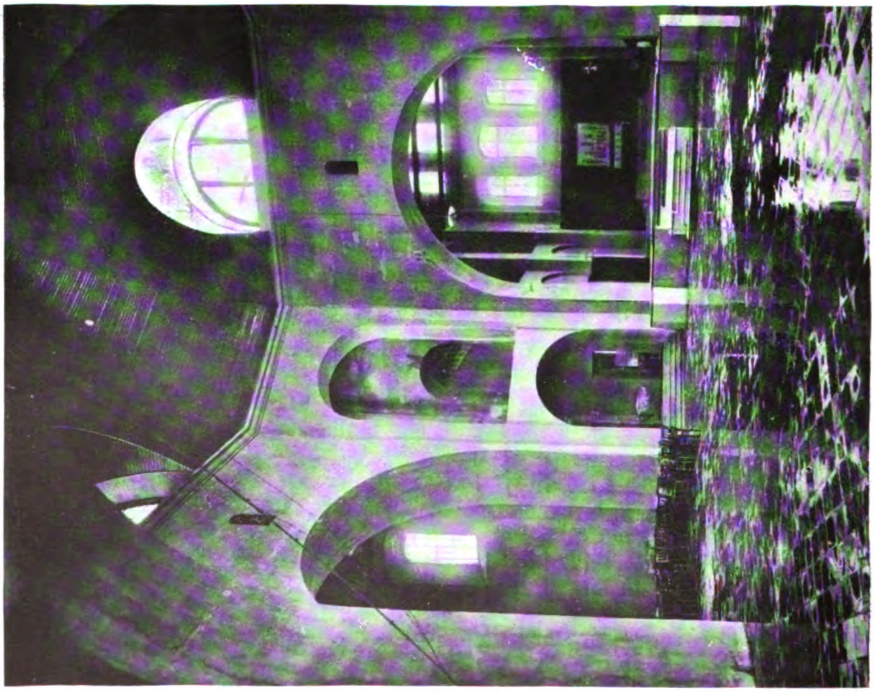
General View from the South-west.



Details of Construction of Nave and Chancel.



AN INTERIOR VIEW LOOKING WEST.



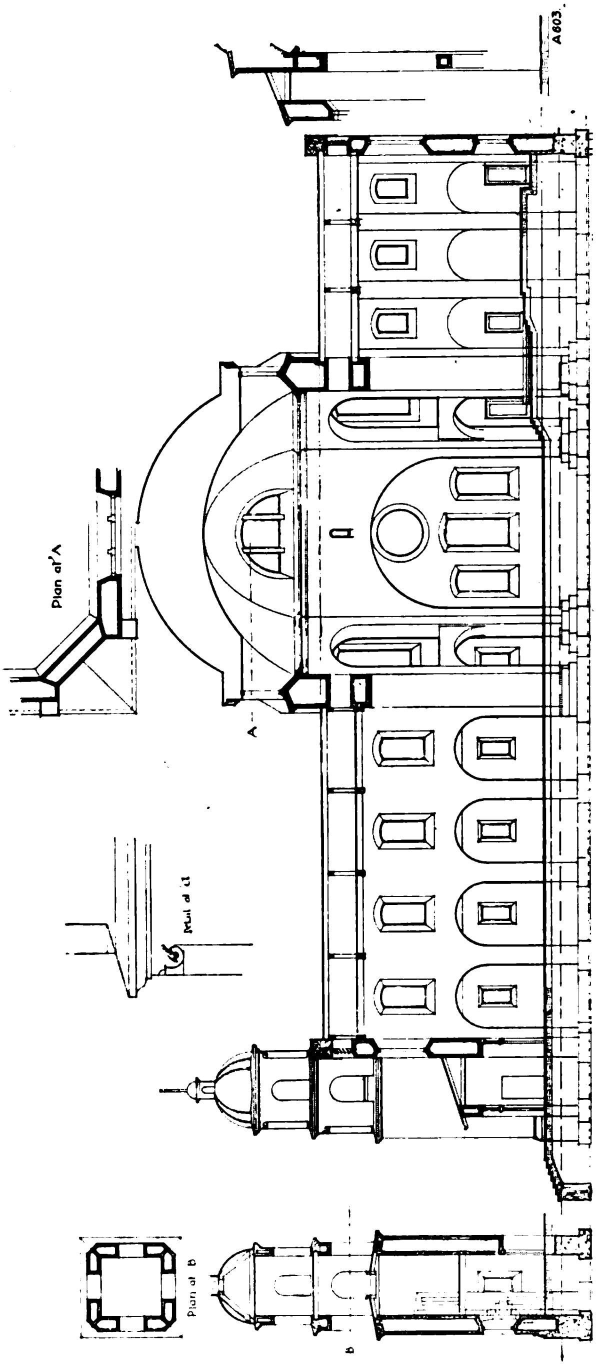
AN INTERIOR VIEW LOOKING EAST.

While reinforced concrete structures are usually intended solely for utilitarian purposes, and cannot as a rule be considered beautiful from the purely artistic point of view, nevertheless a very fair architectural effect can be obtained if due regard be given to questions of proportion and the assimilation of the materials to the special circumstances of the case.

The example from Manila should serve as an instance in this direction, for by following the dignified yet impressive lines of the Spanish Renaissance period, the building, though plain in a marked degree, is yet by no means displeasing to the eye. The interior in particular is most effective.

As may be seen from the plan presented, the edifice is cruciform in shape, and has a seating capacity of over one thousand persons. The dimensions of the nave and chancel are 60 ft. wide by 180 ft. long, the small transepts being 22 ft. long by 18 ft. wide.

The two towers which flank the main entrance on either side are 18 ft. by 18 ft. and 57 ft. high, and the building is reinforced throughout with round, mild steel



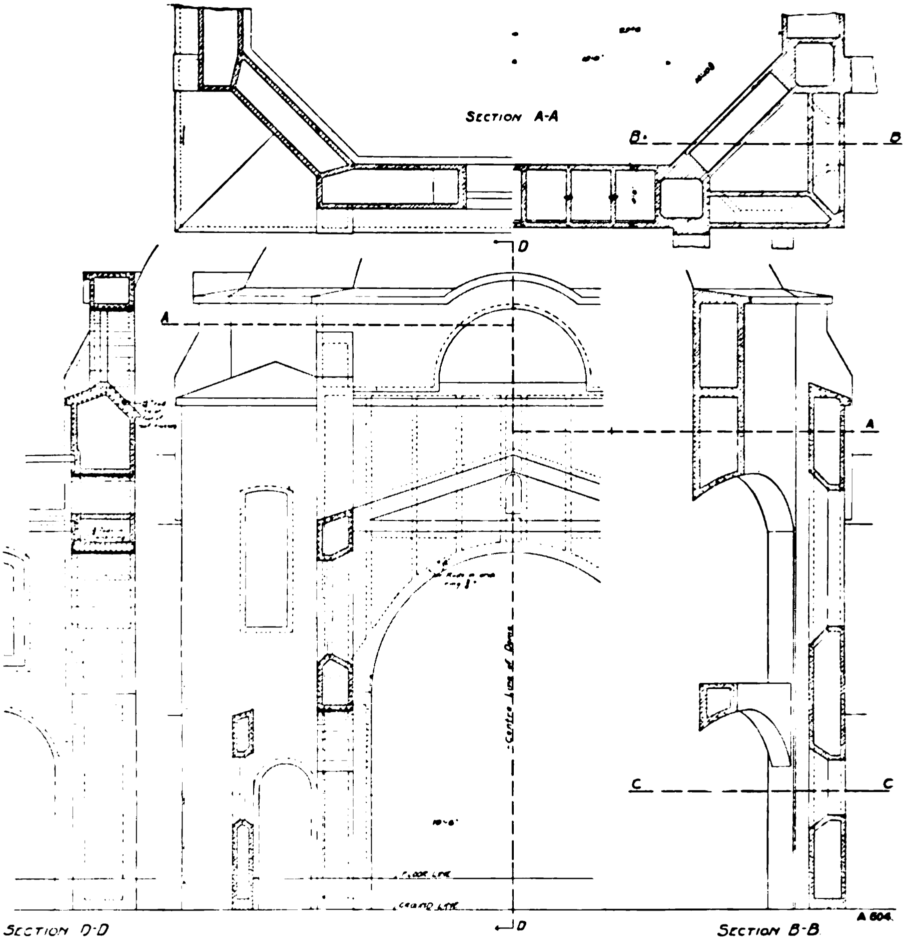
LONGITUDINAL SECTION LOOKING NORTH (AND DETAILS).

rods. The vertical walls are of hollow reinforced concrete, while the floor of the interior is covered with red tiles.

The construction of this building can be best seen from the accompanying reproductions of various plans, which the architects, Messrs. Sturgis and Barton, of Boston, have kindly placed at our disposal, and a good idea of the interior can be obtained from the two photographs, looking east and west.

In view of the investigations which are at present taking place at home into the question of aggregates, we regret we are not in a position to furnish details on this point, as the architects inform us the work was executed under an engineer in Manila, and the composition of the concrete was necessarily left to be decided by him on the basis of the quality of the various materials available.

The cathedral was constructed by the Atlantic Gulf and Pacific Company, and is the gift of Mrs. Mary Bryant Brandegee, of Brookline, Mass.



Half Section through Nave looking toward Chancel

A Reinforced Concrete Boot Factory.

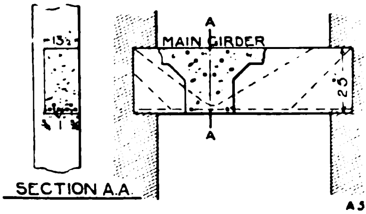
As we have frequently indicated, there is no class of building to which reinforced concrete can be more economically and usefully applied as far as actual cost, maintenance and economy in space is concerned, as in factory work.

We thus have pleasure in presenting details of a Boot Factory which has recently been completed in the Midlands.—ED.

The boot and shoe factory which has recently been completed for Messrs. Rawson and Son, of Leicester, is an excellent example of reinforced concrete work as utilised in a structure for which it is particularly applicable.

The work has been executed by the Empire Stone Co., Ltd., of London, under the supervision of Mr. L. H. Rugg, A.M.Inst.C.E., of Westminster. The architect of the building is Mr. W. H. Simpson, of Leicester. The whole of the reinforcing material consists of indented bars, the Indented Steel Bar Co., Ltd., of Westminster, being responsible for the design of the reinforced concrete portions of the structure.

The original proposal was that the building should be a steel frame structure, but this was afterwards superseded by the application of reinforced concrete throughout, largely for economic reasons, and it should here be remarked that it is particularly in plain buildings of this description, where a number of equal spans and continuous floors of considerable length, and supporting heavy loads, are dealt with, that reinforced concrete effects such a saving of cost in erection and, of course, still more in subsequent upkeep.



LINTEL OVER LIFT—OPENING ABOVE GROUND FLOOR.

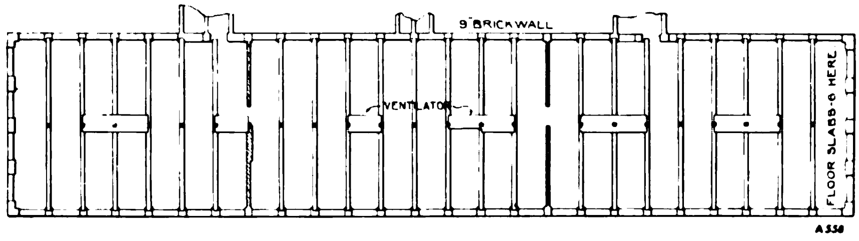
The building measures approximately 250 ft. by 50 ft., and consists of a basement, ground floor, first and second floors, and a large flat concrete roof above, upon which "Vulcanite" roofing has been employed.

From floor to floor the height of the basement is 8 ft. 3 in., of the ground floor 12 ft., of the first floor 11 ft. 9 in., whilst the second floor measures about 10 ft. in the clear.

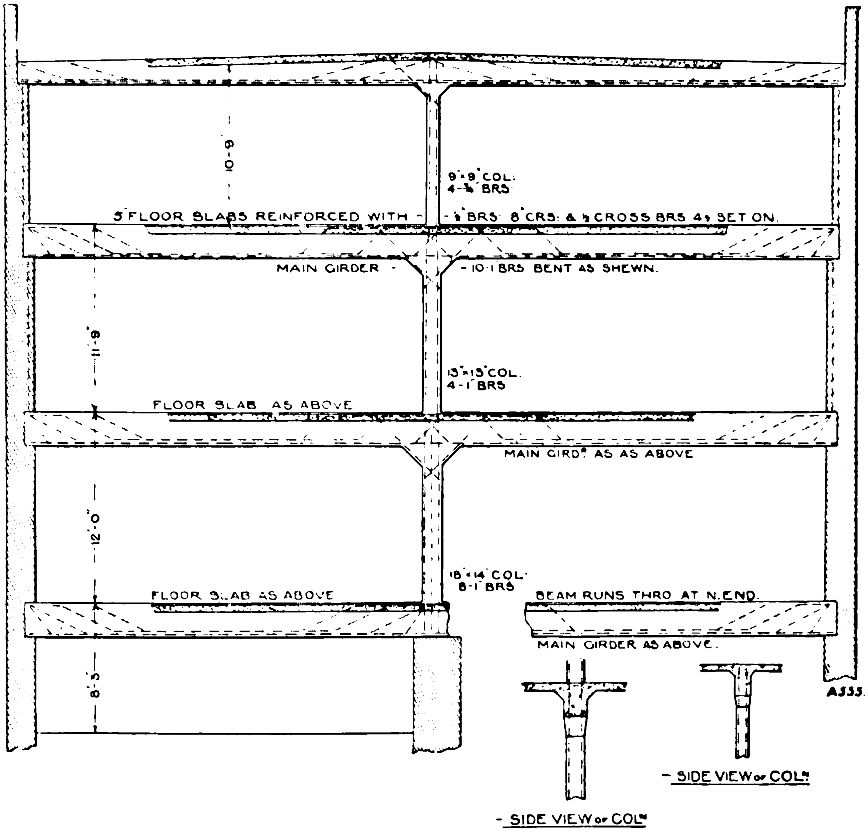
The main beams are 25 ft. span, and are spaced at 10 ft. centre to centre. The floor slabs are 6 in. thick, and the floors are designed to carry a safe load of 3 cwt. per sq. ft., with a factor of safety of 4, whilst the roof is designed to carry 1 cwt. per sq. ft. with the same factor of safety.

The reinforced concrete columns, which in each case support two beams, measure on the ground floor 18 in. by 14 in., on the first floor 13 in. by 13 in., and on the second floor 9 in. by 9 in. They are reinforced by indented bars, the amount of steel varying with the load to be carried.

The foundations of the columns are, of course, of reinforced concrete, and it is also of interest to note that the lintels throughout the building are constructed in the same way.

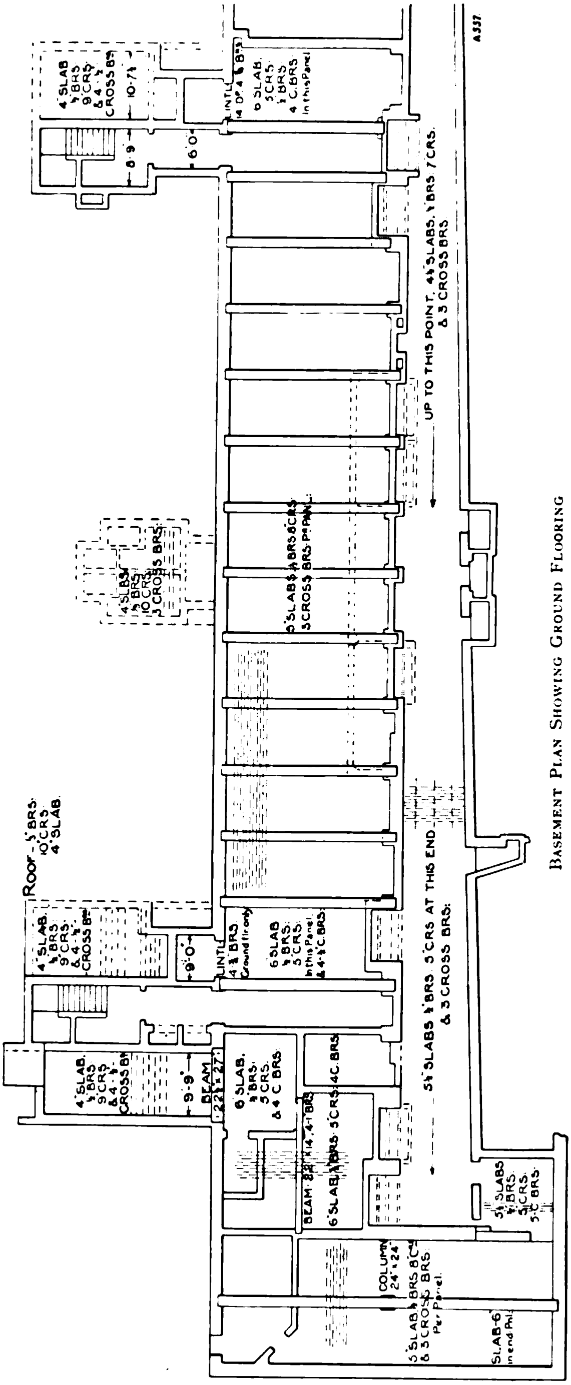


Plan of First Floor.

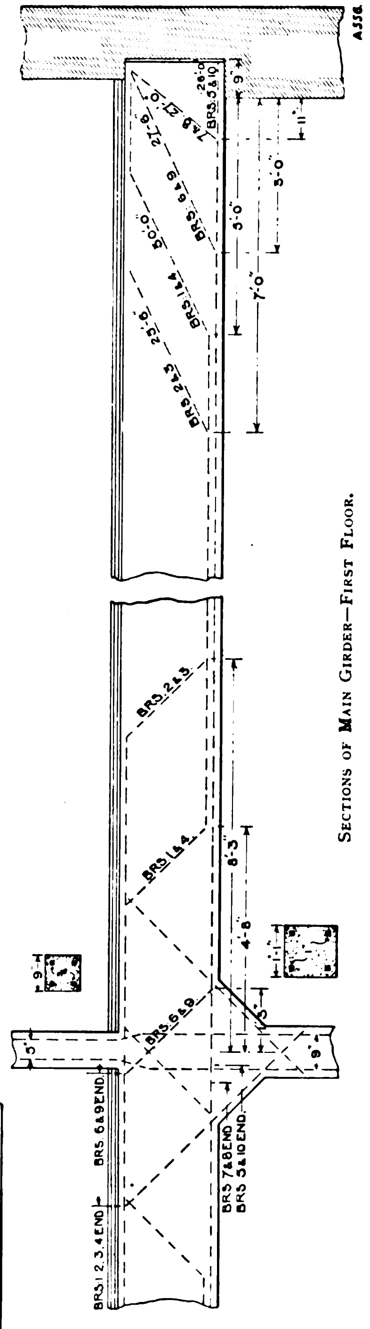


Cross Section Through Main Block.

Regarding the front of the building, this is in brick with artificial stone facings by the Empire Stone Co., Ltd.


A 357
4" SLAB ½" BRS 9 CRS & 4-½" CROSS BRS
10·7½
8·9
6·0
INTL 14 D° 4 ⅝ BRS
6" SLAB 5 CRS ½" BRS 4 C. BRS in this Panel
UP TO THIS POINT, 4½" SLABS, ½" BRS 7 CRS & 3 CROSS BRS
5" SLABS ½" BRS 8 CRS 3 CROSS BRS PER PANEL
4" SLABS ½" BRS 10 CRS 3 CROSS BRS
ROOF - ½" BRS 10 CRS 4" SLAB
4" SLAB ½" BRS 9 CRS & 4-½" CROSS BRS
9·0
INTL 4 ⅝ BRS Ground floor only
6" SLAB ½" BRS 5 CRS in this Panel & 4-½" C. BRS
5½" SLABS ½" BRS 5 CRS AT THIS END & 3 CROSS BRS
4" SLAB ½" BRS 9 CRS & 4-½" CROSS BRS
9·9
BEAM 22½ × 27
6" SLAB ½" BRS 5 CRS & 4 C BRS
BEAM 8¾" × 14. 4-1" BRS
6" SLAB ½" BRS 5 CRS 4 C. BRS
5½" SLABS ½" BRS 5 CRS 5 C BRS
COLUMN 24" × 24"
5" SLAB ½" BRS 8 C'S & 3 CROSS BRS Per Panel
SLAB 6" in end Pnl

Basement Plan Showing Ground Flooring



Sections of Main Girder—First Floor.

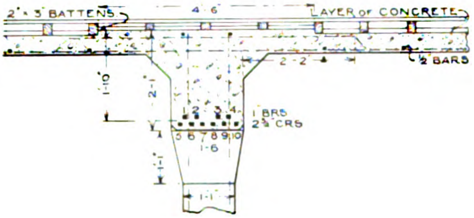
The aggregate of concrete used was all passed through a ¾-in. mesh. It consisted of 4½ parts of stone, 2½ of granite dust, and 1 part of Portland cement, where concrete was used for beams and floor work, while for columns the proportions were materially stronger—*i.e.,* in the ratio of 2½ to 1½ to 1. The concrete was machine mixed throughout, for which the well known Smith mixer was used.

The centering throughout was of an exceptionally substantial character, being 2 in. thick for main beams. The centering was left in place for six weeks before being touched, and when removed the face of the concrete was found to be of very fair surface throughout.

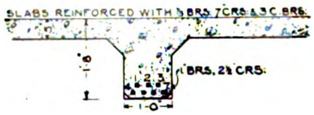
With a view of adding to the fire resistance of the building, the thickness of concrete in the beams around the indented bars was not less than 1½ in., 1-in. bars being used.

The exterior of the Building is faced with red facing bricks and artificial stone dressings, made by the Empire Stone Co., Ltd.; who also contributed the two towers at the rear of the building.

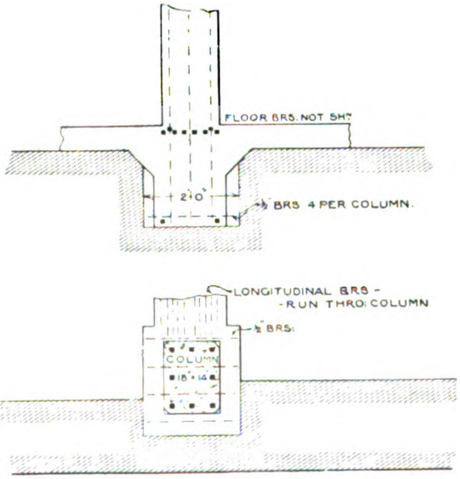
A great feature of the building is the system of heating and ventilation. The



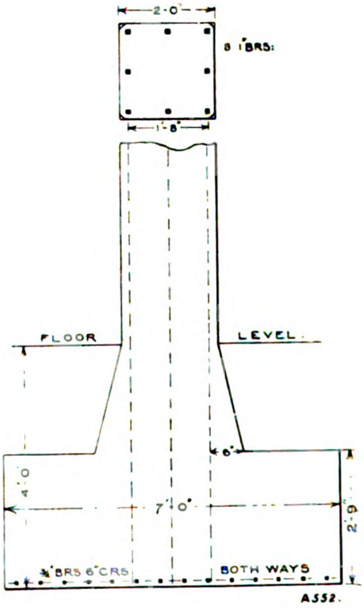
Cross Section of Main Girder.



Section of Roof Girder.

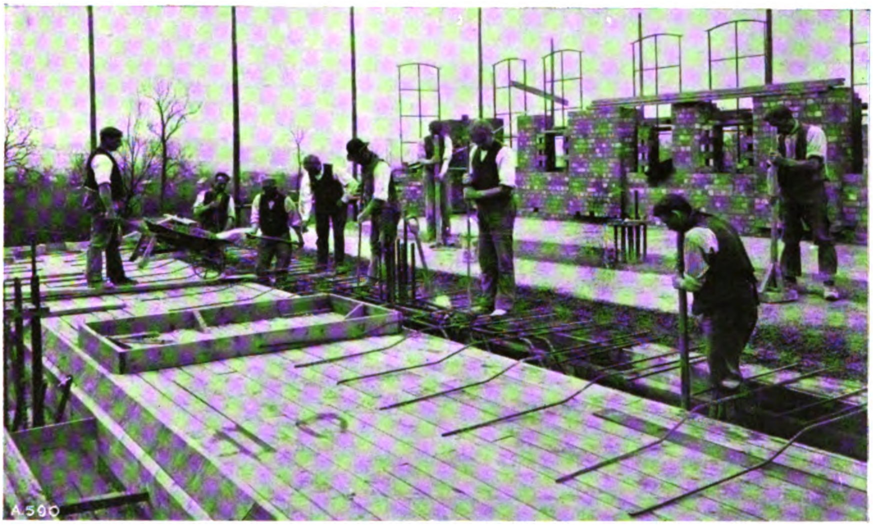


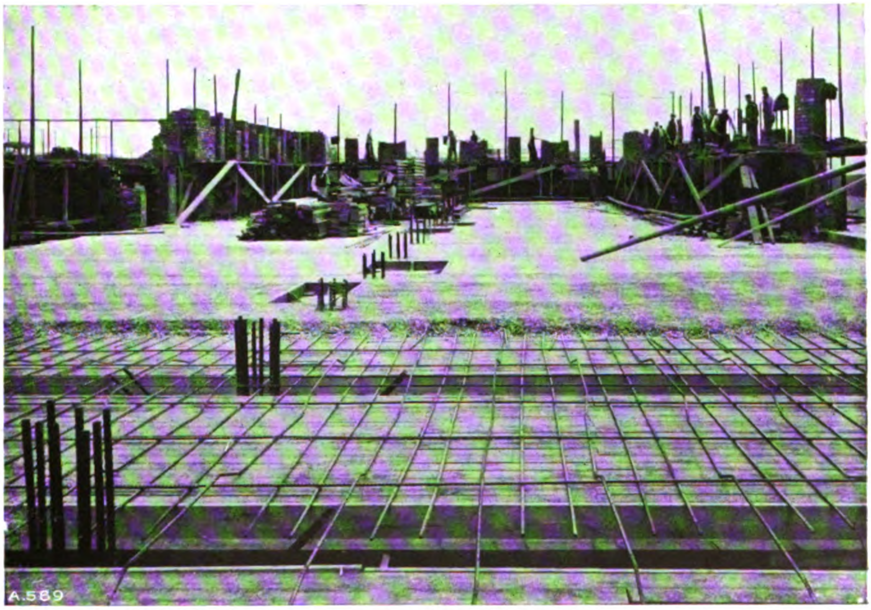
Plan and Elevation of Foundation of Ground Floor Columns on Brick Wall.



Foundation of Basement Column.

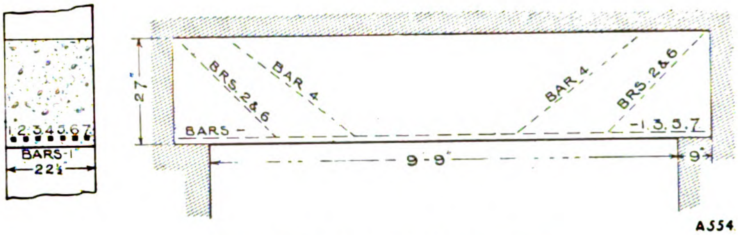
whole of the air in the building is drawn in by special inlet channels in the basement, and can be heated or cooled as required to a given temperature. It is then drawn through a large fan that distributes it into a main air duct running the entire length of the building, 9 ft. by 8 ft.





FLOORS IN COURSE OF CONSTRUCTION.

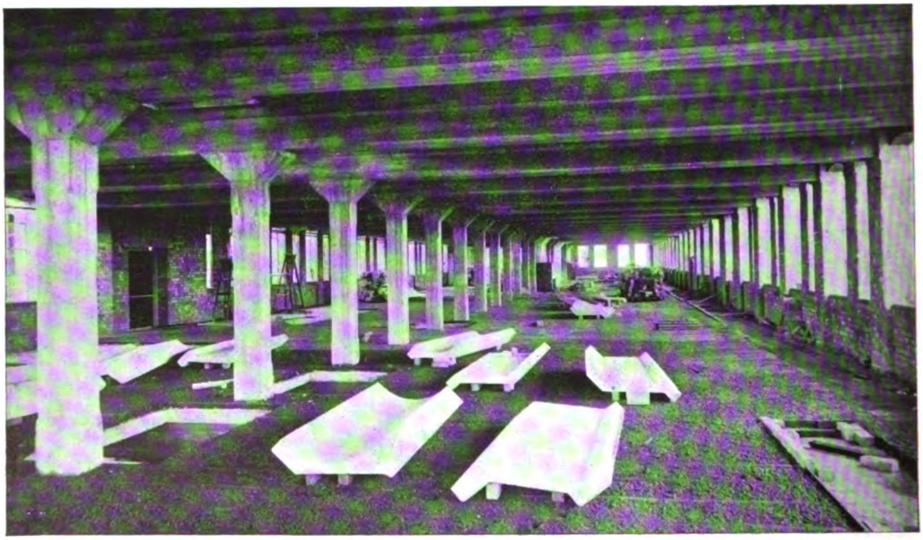
From the main air duct ten shafts ascend to the upper floors. Special exhaust flues and ventilators are provided, and no air is allowed to enter the building except through these flues, none of the windows being made to open.



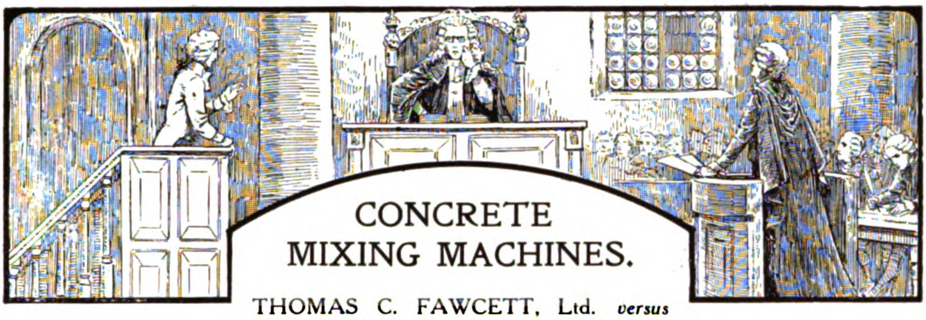
Beam Over Entrance to Boiler House.

All lavatories and staircases, the latter of artificial stone, are situated in two towers, thus leaving the whole of the building free for factory purposes.

The drawings and photographs of the work in course of construction have been placed at our disposal by the Patent Indented Steel Bar Co., Ltd., and the photographs of the work after completion by the Empire Stone Co., Ltd.



An Interior View.



CONCRETE MIXING MACHINES.

THOMAS C. FAWCETT, Ltd. *versus* ORENSTEIN and KOPPELL.*

We present herewith a report on a somewhat interesting case heard at the West Riding Assizes, in respect to the delivery of certain concrete mixing machinery.

The case was certainly one, as the learned judge remarked, which would have been better settled out of court, but as it has received the publicity of a hearing, we deal with it at some length, as it contains a number of points of interest both to purchasers and purveyors of this class of machinery.—ED.

THE above case was heard at the West Riding Assizes, held at Leeds before Mr. Justice Grantham and a jury, on the 22nd, 23rd, and 24th July.

The Plaintiffs, Messrs. Thomas C. Fawcett, Ltd., of the Whitehouse Engineering Works, Hunslet Road, Leeds, were represented by Mr. W. J. Waugh, K.C., and Mr. A. P. Longstaffe; while the Defendants, Messrs. Orenstein and Koppell, of London, appeared by Mr. Tindal Atkinson, K.C., and Mr. H. T. Waddy.

The Plaintiffs' claim was for the price of a concrete mixing machine, being the third of three mixers, supplied to the Defendants. The Defendants admitted this claim, but counterclaimed for £861 10s. 9d. in respect of another mixer supplied to them. The Plaintiffs had already obtained leave to enter judgment for the amount claimed by them, but execution was stayed until the trial of the counterclaim. The defendants are a German limited company, but have a London office, and for some years acted as plaintiffs' agents in the United Kingdom in respect of their concrete mixers. Several of the machines were referred to during the course of the trial. The first was a comparatively small machine, and was mounted on road wheels. This was fairly satisfactory, though certain defects were found, and when the machine concerning which the counterclaim was made was ordered, some improvements were suggested. The latter machine was to be sent to a Mr. Almagia, in Egypt, to which country also the first machine had been sent. The later machine was to differ from the first in two important respects. First it was to be complete with self-contained steam engine; secondly it was to be adapted to run along a broad gauge line. The general principle of the mixers, as such, was the same in each case, as follows:—

DESCRIPTION OF MIXER.

A travelling bucket, which was to be filled with the stones and cement to be mixed together for making the concrete, was mounted on wheels and adapted to be hauled up an inclined guideway by a wire rope passing over a pulley, and winding on to a drum rotated through friction gearing by a steam-engine. When the bucket reached a certain height it encountered a tappet, worked by a hand lever under the control of the operator. This tappet caused the bucket to tip its contents into a hopper. Thence the materials passed into a steel casing, where they were mixed. The mixing was performed by paddles rotated in opposite directions, being mounted on shafts geared together and rotated by spur-wheels from the engine. The mixing drum was carried on a platform raised a suitable distance from the ground and its under side was made to open so that the blocks could be discharged, in the smaller machine, direct into a truck and conveyed to the position they were to occupy. Water was supplied to the mixing chamber; and the paddle arms were fitted with detachable shoes to facilitate renewal.

The actual mixing apparatus of the machine, the subject of the counterclaim, was like that just described, but the mounting was of more elaborate construction in several respects. Thus, instead of being driven by a separate engine through a belt, the steam-engine and boiler were mounted on the same staging as the mixer. The staging was thus considerably larger and heavier. Further, it was surmounted by a corrugated iron roof carried by the same verticals as supported the staging, and was stiffened by lattice-work. The whole machine was adapted to run on a very broad gauge pair of rails, and to be propelled along the same by the power of the engine. For this purpose a long cross shaft was employed, with chain transmission thence to two of the four-flanged rail wheels, one at each side of the machine. The driving gear was considerably geared down, both in the chain transmission and in the spur gearing between the lower chain wheels and the driving flange wheels. All four wheels were double flanged, but no means were provided for holding down the machine to the rails. This mixer was arranged to deposit each block, as made, in the position it was intended to occupy.

---

* Reported by DOUGLAS LEECHMAN, ESQ., A.I.M.E., Barrister-at-Law.

THE CASE.

In giving the order, both Mr. Almagia and the Defendants pressed for a certain guaranteed output, but the Plaintiffs were not disposed to agree to this. Eventually the order was accepted and executed, and when the mixer was put together the Defendants saw it in position. It was not put to a thorough test, and the Defendants called attention to the fact that the vibration was considerable. In reply, it was contended that the parts were only put together temporarily, but it would be all right when they were properly erected for working purposes. The mixer was eventually despatched and arrived in Egypt, where it was put together after some difficulty and set to work. Some of the parts had been lost or broken and otherwise damaged on the way, and some of these were replaced. When the machine was got to work Mr. Almagia found that it would not produce at the rate he desired, and that owing to the vibration and loose fitting of some of the bolts, frequent stoppages for overhauling were necessary; and further that the boiler was not up to the work. Several attempts were made to get the machine to work satisfactorily, but in the end Mr. Almagia refused to take it. On the Defendants complaining to the Plaintiffs as to the unsatisfactory way in which the machine behaved, the Plaintiffs expressed the opinion that there must be something radically wrong with the way in which the machine was being worked, and that it could not have been properly fitted up.

The Defendants wrote to the Plaintiffs suggesting that a reliable mechanic and one used to working these machines should be sent to Egypt to put the machine into proper order. If the mechanic succeeded in making the mixer fit for work they would pay the cost of sending him, but if he failed to do so the mixer should be held at the Plaintiffs' disposal, and they (the Plaintiffs) should be debited with the mechanic's expenses. The Plaintiffs replied that they were quite willing to send out a man at the remuneration suggested by the Defendants, but they (the Plaintiffs) could not accept any stipulation with respect to the machine being at their disposal if it did not answer the client's requirements. Eventually the Defendant's Egyptian manager expressed the opinion that it would be useless to send out the mechanic, as the mixer was in too bad a state to be put into proper working order.

Another offer was that the machine should be sent back from Egypt and placed at the disposal of the Plaintiffs, who should refund the actual payment to the Defendants and half of the other expenditure incurred. But the Plaintiffs' reply was that they were not able to fall in with either of these proposals; further, they requested payment for the other machine then on order, and it was in respect of this order that the Plaintiffs obtained judgment on the original claim.

The counterclaim was made up of £530 0s. 6d., the price of the machine; freight to Egypt, erecting and testing, etc., £189 15s. 9d., and loss of profit £141 14s. 6d., *i.e.*, together £861 10s. 9d.

EVIDENCE.

At the trial Mr. Philip Deutsch, the Defendants' London manager, gave evidence in support of the counterclaim, and maintained in cross-examination that complaints had been made as to the earlier mixers supplied by the Plaintiffs. The Plaintiffs contended that the unsatisfactory results obtained from the machine were due to the defective manner in which it was fitted up and to the way in which it was worked. Most of Defendants' evidence was taken in Egypt, and was read in Court. It bore out the Defendants' case.

Mr. E. W. Dixon, civil engineer, stated that the framework which carried the corrugated iron roof for the machine was not sufficiently rigid, and the vibration was bound to shake it to pieces.

Mr. J. D. Fawcett, Plaintiffs' managing director, testified that the machine had been put to work before being sent out, and had worked satisfactorily

THE JUDGMENT.

In summing up his Lordship regretted that the offers made by the Defendants (Messrs. Orenstein and Koppell) for settlement had not been accepted.

The jury found a verdict for the Defendants on the counterclaim for £300, and his Lordship delivered judgment accordingly.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The Stability of Concrete under Earthquake Shock.—In a recent issue we referred in our Editorial Notes to a house in Kingston, Jamaica, which had withstood the earthquake shocks in a most remarkable manner. Below we have pleasure in presenting a photograph of the interior, which we are able to reproduce by the courtesy of the *Cement Age*. It withstood the series of severe shocks without the slightest crack or other effect.

AN UNDAMAGED CONCRETE HOUSE AT JAMAICA AFTER THE EARTHQUAKE.

Railway Work Under Earthquake Shock.— An interesting report on the effect of the earthquake on the railways near Jamaica has been recently published in the *Engineering Record* (U.S.A.), and we give the following extracts, which should prove interesting reading :—

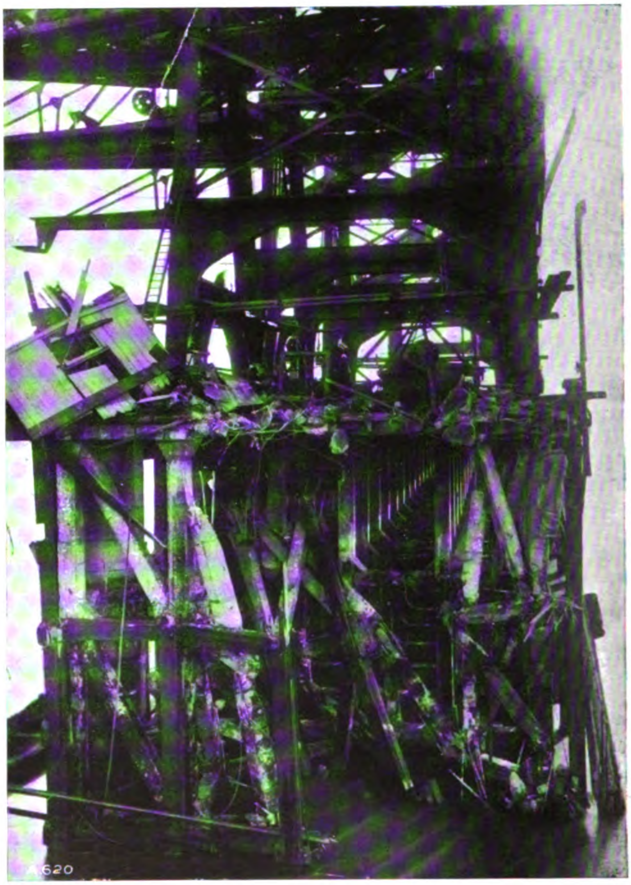
"The more important structures, such as bridges, viaducts and tunnels, remain intact. The abutment and piers of bridges are nearly all of concrete without reinforcement, and with the exception of a little spalling under the seat of girders, show no signs of the very severe strains to which they were subjected. Viaducts of concrete, without reinforcement, are uninjured, as are 20 to 30 ft. span concrete arch bridges under and over the track.

"The tunnels are, where necessary, lined with concrete, and in some cases show slight cracks, commencing near the junction of the invert with the side wall, and extending vertically about 6 ft. The cracks are superficial, and do not weaken the structures appreciably.

"Concrete retaining walls without reinforcement withstood the shock well, and were not damaged. A concrete sea protective wall, which had been completed only two weeks, suffered no damage. The wall is carried below sea level 5 ft., and rests partly upon hard blue clay, and partly upon igneous rock, and extends 16 ft. above sea level. It is built of 1 : 3 : 6 Portland cement concrete below and 1 : 4 : 8 Portland cement concrete above sea level, clean sea sand being used for the mortar. Hard limestone broken to 2½ in. gauge by hand labour was used for the aggregate. The wall is 8 ft. thick at the base and up to sea level, after which it is battened and stepped to a thickness of 1½ ft. at the top. No reinforcement is used."

Resistance of a Reinforced Concrete Pier in a Severe Collision.—In the course of the discussion on reinforced concrete at the recent Engineering Conference (dealt with in our July issue, No. 3, Vol. II.), much interest was aroused in the particulars presented by Mr. Meik, M.I.C.E., on an accident at the Purfleet reinforced concrete pier, when a steamer came into collision with the pier in question.

The steamers lie on one side and discharge across the pier into barges. Dolphines protect the pier from collision at either end, but an 8,000 ton steamer, the S.S. "Clavering," got out of control, and carried away 8 piles, very nearly bringing down one of the large cranes which was overhanging at the time.



Purfleet Pier after the Collision in January Last.
(The cranes remained standing)

The pier, however, withstood the shock in a manner that would have been practically impossible if any form of construction other than reinforced concrete had been employed, although the wreckage was considerable and the pier had to be re-constructed for about 20 ft.

No serious difficulty was met with in this re-construction, and many of the arguments as to the difficulty of repairing reinforced concrete were negatived.

A point of considerable importance ascertained in connection with these repairs was that when the concrete was cut away and the steel exposed, the steel reinforcement was found in the identical condition as when it was originally put in some years back.

Strength of Concrete.—In his paper on the Simplon Tunnel, Mr. Francis Fox, M.Inst.C.E., recently stated that in November, 1901, the advanced gallery on the Italian side entered at 2.748 miles a formation consisting of calcareous mica-schist entirely decomposed; the drills had to be withdrawn and the work proceeded by hand. Heavy and close timbering of the entire gallery on both sides, as well as on roof and floor, had to be done immediately, and although whole timbers were used they were completely crushed, and for the time the heading was lost. The miners were withdrawn, and a fresh start was made by inserting heavy rolled steel beams (16 in. deep) bolted together, with balks of pitch-pine 20 in. by 20 in. between them, but the pressure deformed this girder-work, shearing the bolts and crushing the timber into splinters. As a last resource, the space between the beams was speedily rammed full of quick-setting Portland cement concrete, and this held, thus the advance after a delay of six months was resumed. The lining of this portion of the tunnel was a matter of the greatest difficulty, and cost £1,000 per yard.

Reinforced Concrete Water Mains.—A new reinforced concrete rising main is to be constructed for the City of Norwich Corporation on the Bonna system, the diameter being 33 in. and the length 2½ miles. It will be utilised for the conveyance of the sewage of the City from the Pumping Station at Trowse to the sewage treatment works at the Sewage farm at Whitlingham. The pipes will be subject to a working head varying between 117 ft. at the Trowse end, and 10 ft. at the sewage tanks end, and to further pressures due to the oscillations arising from pumping.

The work will be carried out from the designs and under the supervision of Mr. Arthur E. Collins, M.Inst.C.E., City Engineer, and the contract will be in the hands of the Columbian Fireproofing Co., Ltd., of London.

The Economy of Small Reinforced Concrete Bridges.—At the recent meeting of the Kent County Council, it was stated that a reinforced concrete bridge designed on the Hennebique system was to be constructed across the river Medway between Halling and Wouldham. The reinforced concrete bridge was decided upon in preference to other forms of bridge construction for reasons of economy.

Reinforced Concrete Work on the Hennebique System in England.—The increasing popularity of reinforced concrete work in the United Kingdom is perhaps best shown from the extensive list of works recently contracted for by the licensees of the Hennebique system.

Among the bridges so contracted for are the Stakeford Bridge, Northumberland, and the Harewood and the Cranbeck Bridges, Yorkshire.

Among marine works are the Coast Protection Works, near Brighton, on the Owens-Case system, and a berth in the Southampton Quays, 500 ft. long.

Of water reservoirs, there is one at Poole, with a capacity of 520,000 gallons.

Of factory buildings we observe the following firms are either having new buildings, or extensions to present buildings, carried out in reinforced concrete:—Messrs. Reckitt and Sons, of Hull; Ritchie, Hart and Co., of Belfast; James Watson, Ltd., Dundee; and A. J. Kidd and Son, of the same town, while the Preston Co-Operative Society are erecting new offices.

The list of these works is the more interesting, showing as it does the diversity of applications to which reinforced concrete is being put.

The Yorkshire Hennebique Contracting Co., Ltd., have obtained a large proportion of these contracts.

Reinforced Concrete Work on the Coignet System in England.—Another list—*i.e.*, one from Messrs. Coignet, shows that among the works their licensees have in hand are a second tobacco warehouse in the Cumberland Basin, Bristol, three warehouses for Messrs. J. C. and J. Field, Ltd., of Rainham; and among minor works the underpinning of the Newhaven Quay wall, involving no less than 700 piles, a retaining wall for the Wolseley Motor Car Co., some strong rooms for the London and County Banking Co., Mr. Stewart Dawson, of Hatton Garden, and Messrs. Thorneycroft, at Southampton, while among tanks we observe one for the borough of Elgin, Scotland. The diversity of application is also notable in respect to these examples.

Portland Cement Brickwork.—Sir Weetman D. Pearson, Bart., M.P., the well-known contractor, recently speaking on matters appertaining to Portland cement, made the following statement:—"I base my opinion that the demand for Portland cement will continue to increase, upon the fact—which is not yet fully appreciated by architects and builders—that cement mortar is as cheap, if not cheaper, than lime mortar, whilst in the former case we are absolutely sure of getting strong, solid work, whereas, as we all know, lime is to some extent an uncertain factor. Where Portland cement, of the quality such as is made by your company, can be delivered not exceeding 30s. per ton, cement mortar is as cheap as lime mortar if lime costs 15s. a ton. In the former case, six to eight parts of sand can be used to one part of cement, whereas in the latter case three to at most four parts of sand can be used with one part of lime. I am sure that, once this far-reaching and important fact is widely known, the use of cement mortar for all purposes will largely displace lime."

Concrete Machinery.—We learn that the Ideal Concrete Machinery Company, of South Bend, Indiana, have recently completed large orders for the following towns:—Auckland, N.Z.; Sydney, Australia; Kobe, Japan; Calcutta, India; Shanghai, China; Buenos Ayres, Argentine Republic; Rio de Janeiro, Brazil; Lima, Peru; Monte Video, Uruguay; Buda Pest, Hungary, and in Chili. This certainly indicates the growing application of concrete blocks in all parts of the world, and particularly where clay or ordinary bricks are difficult and expensive to obtain.

A Useful Reference Book.—We have much pleasure in noticing "Concrete Steel Buildings" (compiled by Mr. W. Noble Twelvetrees, M.Inst.M.E.), in which are illustrated a number of interesting structures in which reinforced concrete has been adopted. The volume is a useful summary of recent British examples of reinforced concrete work already published in this journal, and elsewhere, while it contains several descriptions of works which have not yet appeared in any English journal, notably some data on the new General Post Office, which we refer to elsewhere in these columns. The book, which is profusely illustrated, is well worth having for reference purposes, and has been published by Messrs. Whittaker & Co.

But why the term "Concrete-Steel"? Reinforced Concrete is the more expressive term, and the one more generally used.

A Correction.—A correspondent points out that in our article in the July issue on the Concrete Domes in the Westminster Cathedral, in the sentence reading "The circle developed by the pendentives is 60 ft. in diameter, the base of the dome is corbelled over from this, so that the springing is clearly defined, and a salient angle is thus *avoided*, for the convenience of the mosaic workers of a future generation." This should read, "is thus *provided*," and we are obliged to our correspondent for pointing out this clerical error.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

THE NEW GENERAL POST OFFICE.

WE have received numerous enquiries regarding the new General Post Office, which is to be constructed in reinforced concrete, and although it is our intention to reserve space in a later issue to deal with this very important building at length, and to present numerous illustrations of the work in course of construction, when it has been further proceded with, yet we are taking this opportunity of presenting some data which have been supplied to us, together with two drawings which Messrs. Whittaker & Co., the publishers of "Concrete Steel-Buildings," have kindly placed at our disposal.* These will clearly show the importance of the structure, or rather structures, which together comprise over eight million cubic feet.

The new General Post Office will be located opposite the General Post Office North, and has been designed by Sir Henry Tanner, I.S.O., principal architect to H.M. Office of Works, the Hennebique system of reinforced concrete having been adopted throughout. Messrs. Holloway Bros. have been appointed con-

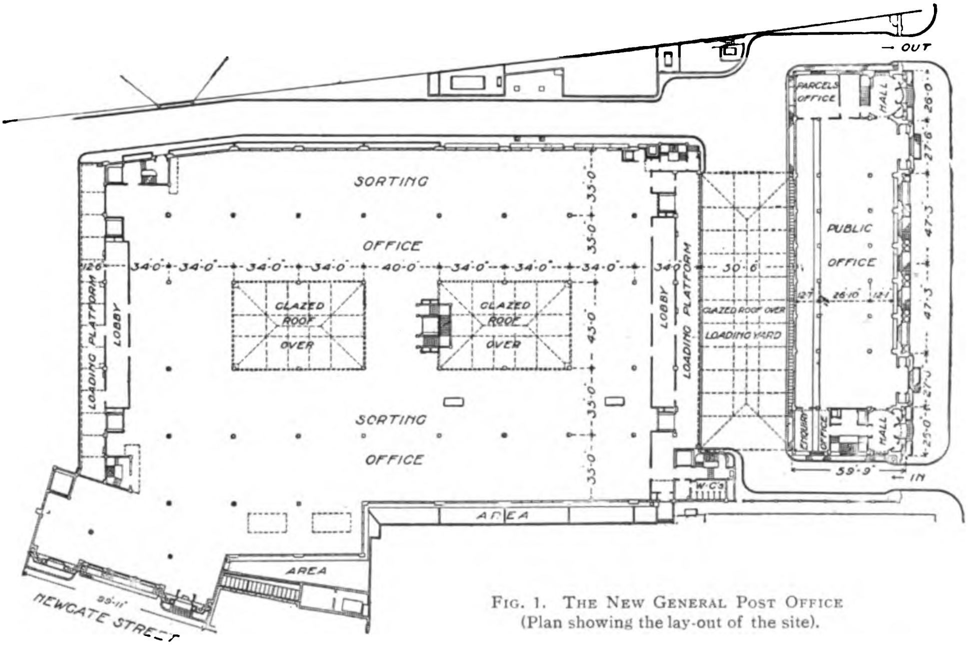


FIG. 1. THE NEW GENERAL POST OFFICE (Plan showing the lay-out of the site).

---

* "Concrete Steel Buildings," by W. Noble Twelvetrees, M.Inst.M.E. Whittaker & Co., 1907.

tractors, and the cement used will be the Hilton Anderson Brand, of the Associated Portland Cement Manufacturers (1900), Ltd.

The new building practically comprises two blocks, one known as the Public Office, the other as the Sorting Office.

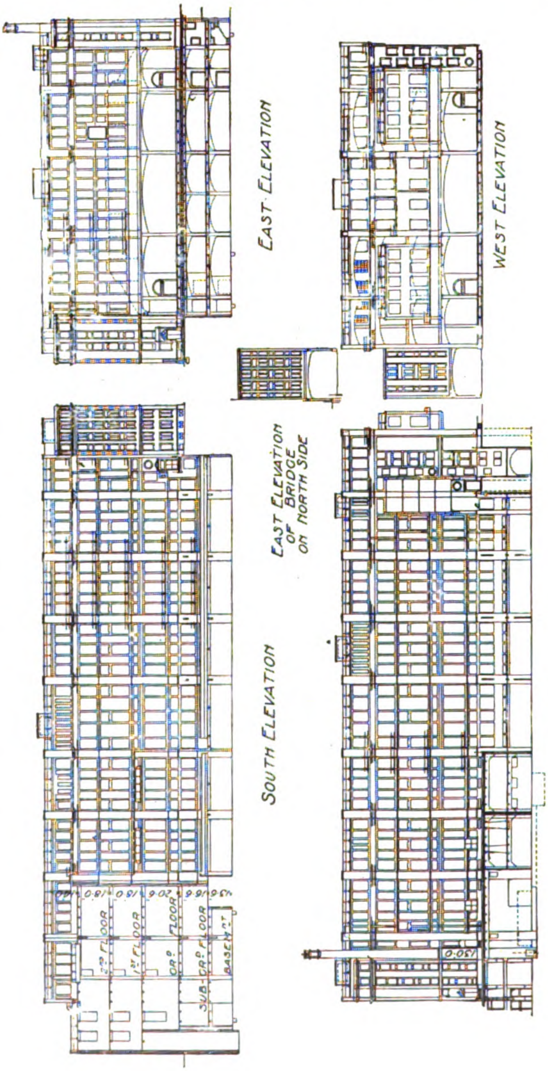


FIG. 2. THE NEW GENERAL POST OFFICE.

The Public Office.—The main dimensions of the Public Office are 201 ft. long by 60 ft. wide, the height being 85 ft. above ground, while the total height from sub-basement level to the flat roof is 109 ft. The cubic contents is approximateiy one and a quarter million cubic feet, a capacity which is, of course, in this case only possible in the City of London, owing to the fact that Government buildings are exempt from the London Building Act. This block has six floors, of which the ground floor is 25 ft. high, and the other floors of varying heights averaging 13 ft. 6 in. from floor to floor.

The Sorting Office.—The Sorting Office is a far larger structure than the Public Office, being 312 ft. by 185 ft., with a height of 63 ft. above ground, or 100 ft. from sub-basement to the flat roof, while it carries a cubic capacity of no less than 5,780,000 cubic ft. As the building contains no large party or divisional walls, it may be taken as about 23 times the cubic contents of an ordinary structure in the City of London. Here the floors have somewhat different dimensions as to height, the basement being 13 ft. 6 in., the sub-ground floor 16 ft. 6 in., and the ground floor 20 ft. 6 in., while the remaining three floors are 18 ft., 18 ft., and 14 ft. respectively.

Intermediate Building.—Between the two buildings there is to be a large covered yard with a glazed roof over for the accommodation of the Post Office vans, the covered portion being about 150 ft. by 50 ft. Below this yard is a large basement which contains storage rooms, the boiler house, and various offices, and which has a cubic contents of over 900,000 cubic ft.

General Design.—The design and lay-out of these reinforced concrete buildings is eminently simple and practical, and the structure lends itself in almost every way to the application of reinforced concrete. The economy in the application of reinforced concrete in this instance is particularly obvious, as ordinary forms of construction would have meant great waste of material and space.

A point of more than ordinary technical interest in this building, which we ought to mention, is the loading platform, which is constructed on reinforced concrete cantilevers.

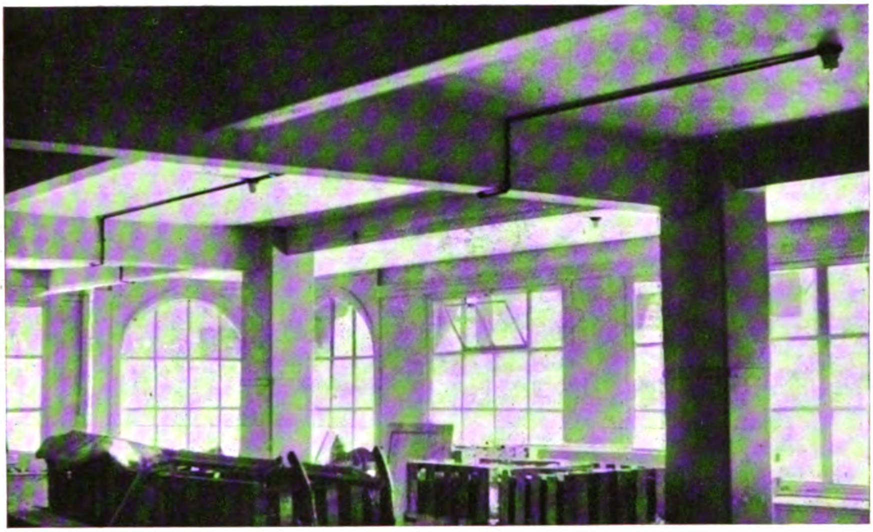


Fig. 3. Messrs. Grossmith's Factory, Showing Under Side of First Floor.

The general lay-out of the structure may be seen from the accompanying plans and sections.

REINFORCED CONCRETE FACTORY WORK.

Some new premises for Messrs. Grossmith, Sons & Co., perfumers, have just been erected on the Coignet system of reinforced concrete at the corner of Ivy Lane and Duke's Head Passage, Newgate Street, E.C.

The building is composed of nine floors in reinforced concrete, supported by posts, the exterior walls being made of brickwork, with reinforced concrete lintels, and the roof, which contains two floors, is of peculiarly intricate construction.

It may be described as a skew gable roof, none of the sides being equal. This constituted a great difficulty on account of the uneven thrusts, which had to be taken up by using the floors as ties. Owing to want of space, all the framework was made beforehand at the contractor's works, and then conveyed to the site. This was rendered possible by the fact that on the Coignet system the framework can be prepared in such a manner as to be transportable without any of the bars working loose.

Owing to the narrowness of the street and the height of the adjoining houses, it has been impossible to obtain a photograph of the entire building. *Fig.* 3 is of the interior, showing under side of first floor. The scantlings of the posts are 12 in. by 12 in., main beams are 5 in. by 12 in., and the smaller beams are 4 in. by 8 in. The thickness of the slab is $3\frac{1}{2}$ in., and the superloads on floors are $1\frac{1}{2}$ to 2 cwts. per sq. ft.

Fig. 4 shows interior under the eighth floor, with dormers, and *Fig.* 5 shows the general slab on the roof, which is 3 in. thick and covered with slates.

The architect for the work was Mr. H. A. Saul, A.R.I.B.A., the contractors for the reinforced concrete work Messrs. Peacock Brothers, Water Lane, Brixton, S.W., and the general contractors were Messrs. Lawrence and Sons, 14, 15 and 16, Wharf Road, N.

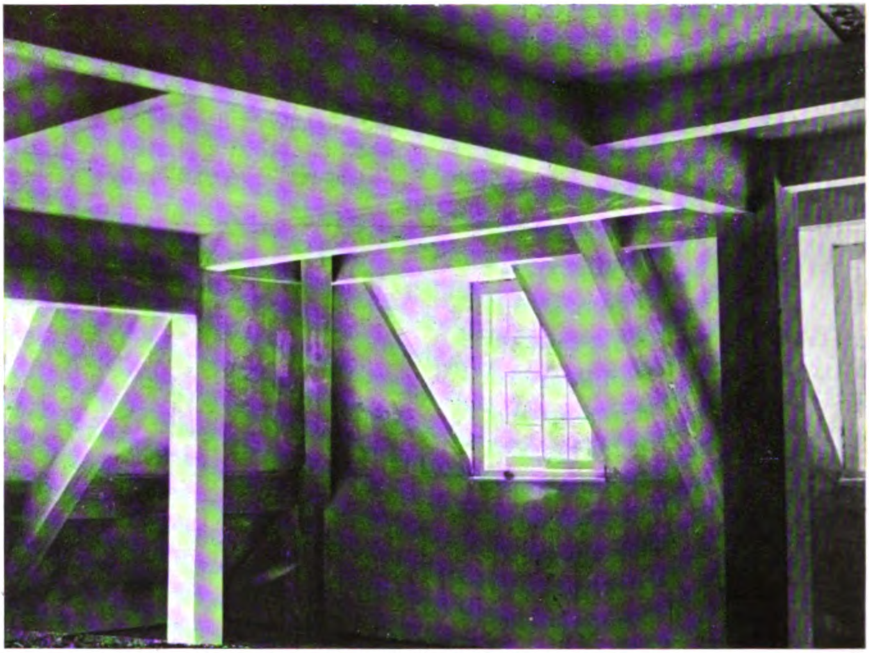


FIG. 4. UNDER SIDE OF EIGHTH FLOOR.

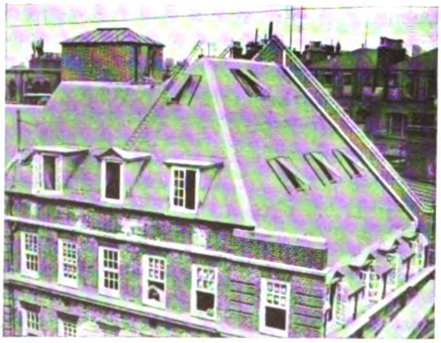


FIG. 5. THE ROOF.

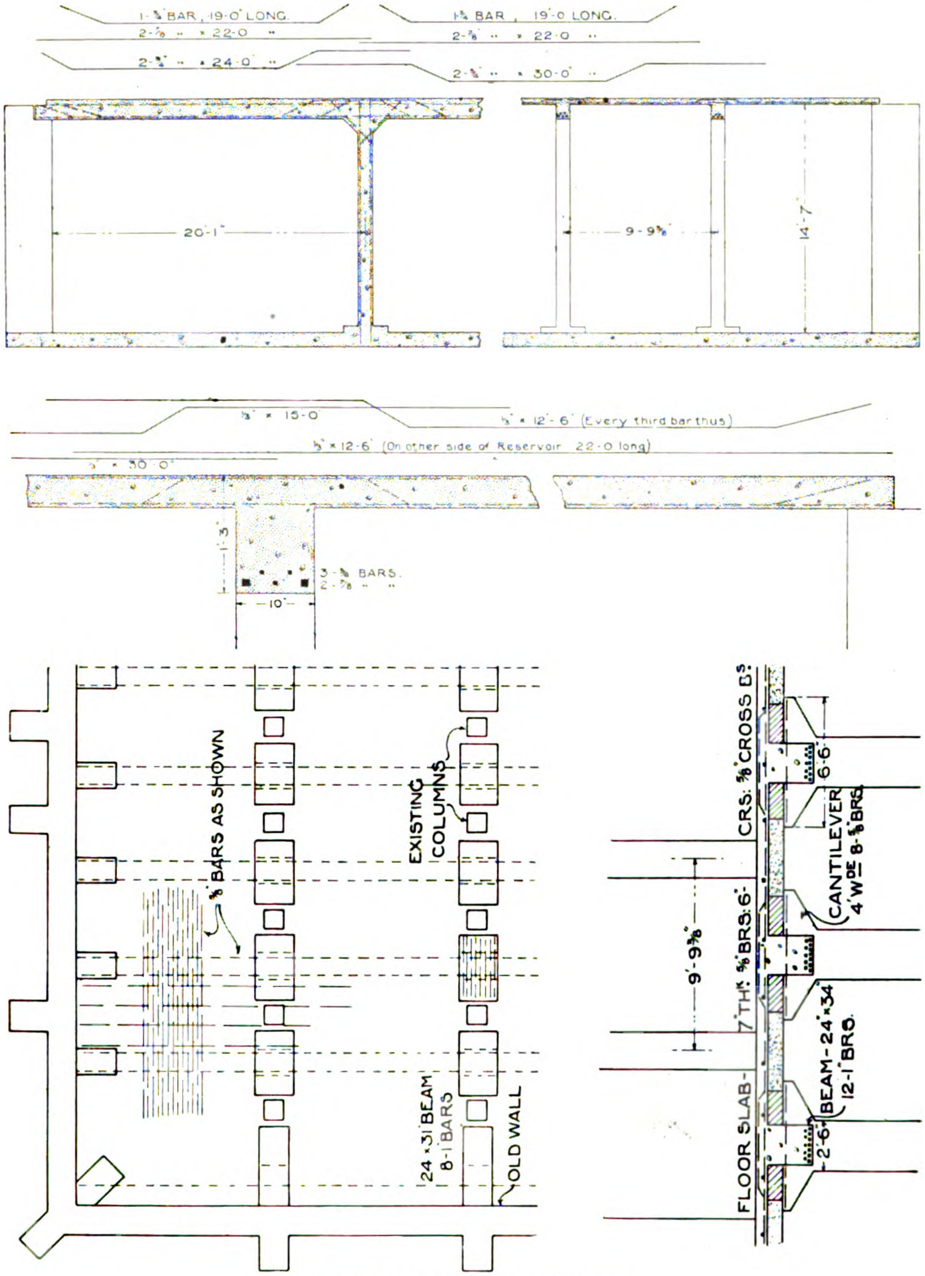
DOWNSIDE ABBEY RESERVOIR.

AN example of reservoir construction illustrating the superiority of reinforced concrete for structures of the kind over heavy masonry, is afforded by the reservoir built for the supply of water to Downside Abbey, near Bath, and to one or two of the villages in the neighbourhood.

As at first built, the structure included heavy masonry walls 3 ft. thick, a light concrete floor reinforced with Kahn "trussed bars," and a concrete roof supported by columns of the same material, these portions of the work being reinforced by "indented" bars.

Fig. 6 contains three sections, making clear the details of the original design. The ground was particularly unsuitable for carrying the weight of a reservoir constructed of heavy masonry, as it consists of boulders, sandstone, and agglomerate, embedded in soft and yielding clay. When affected by moisture, the clay is pressed into the crevices between the boulders by the weight of the superincumbent earth, and large hollows are sometimes formed in the underlying strata by displacement and erosion of the clay.

Some time after the completion of the reservoir, cracks developed in the floor owing to settlement of the subsoil, and the water escaping through these cracks probably had the effect of washing away part of the clay between the boulders, the



FIGS. 6 & 7. DOWNSIDE ABBEY RESERVOIR

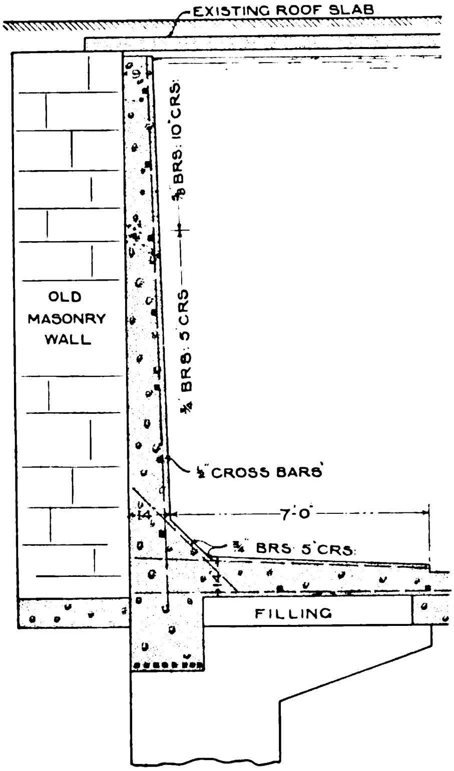


Fig. 8.

result being that a portion of the masonry walls and one corner of the floor on which they stood collapsed entirely, thus necessitating the reconstruction of the greater part of the reservoir. It ought to be clearly recognised that the failure in no way reflects upon the reliability of reinforced concrete, nor upon that of the two forms of patent bars employed. On the contrary, the mishap is attributable entirely to the excessive weight of the masonry construction, which, in this, as in many other cases that could be cited, defeated its own object by imposing undue local pressure upon the ground, the sinking of which allowed the weight of the masonry to come upon the reinforced concrete floor, whose resistance had been calculated on the usual assumption that the walls would be self-supporting.

So well were the " indented bars " able to withstand the severe test thus imposed upon them, that it was decided to employ the same type of bar in reconstructing the reservoir, this time entirely in reinforced concrete. In the new design the engineer did not rely upon the method, which has been applied with perfect success in other places where the soil is of unreliable character, of constructing the reservoir as a monolithic tank on a continuous foundation slab capable of withstanding the strains due to any local settlement. In view of previous experience it was thought desirable to sink a number of concrete piers 4 ft. by 2 ft. 6 in. all over the area covered by the reservoir floor, as shown in *Fig.* 7, the piers being carried down to solid rock occurring at the depth of from 20 ft. to 25 ft. The upper end of each pier was extended by two cantilever projections as represented in cross section *Fig.* 7, these cantilevers being reinforced by ⅝ in. indented bars.

Reinforced concrete beams 24 in. wide by 27 in. deep were built upon the piers and connected with a new floor slab 7 in. thick. The new side walls of the reservoir are of reinforced concrete, built monolithic with the floor construction, and the reinforcing bars are securely anchored into the concrete of the adjoining members, as illustrated in *Fig.* 8, which is a section through one of the walls, and part of the floor. The old masonry walls have been allowed to remain in position, where they afford horizontal support to the inner walls of reinforced concrete. *Fig.* 9 is from a photograph of the original reservoir taken during the construction of the columns and roof. The latter portions of the work were uninjured by the subsidence except near one corner, and have been left in position. The cantilever projections of the plain concrete piers afford additional support for the columns as they extend up to the footings of the columns. Two of the columns which were injured at the time of the collapse have been rebuilt in accordance with the original plans.

The reservoir was built and reconstructed from the designs and under the superintendence of Mr. F. P. Whiteside, the plans for reconstruction having been prepared in accordance with the system of the Patent Indented Steel Bar Co., of Westminster.

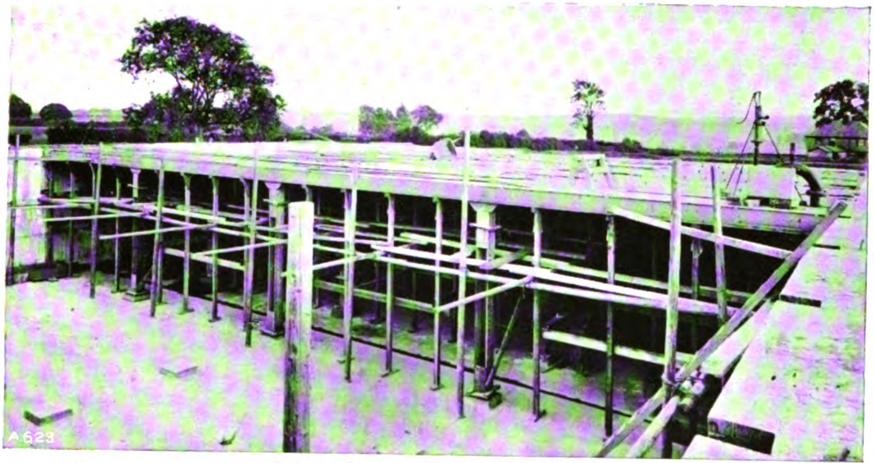
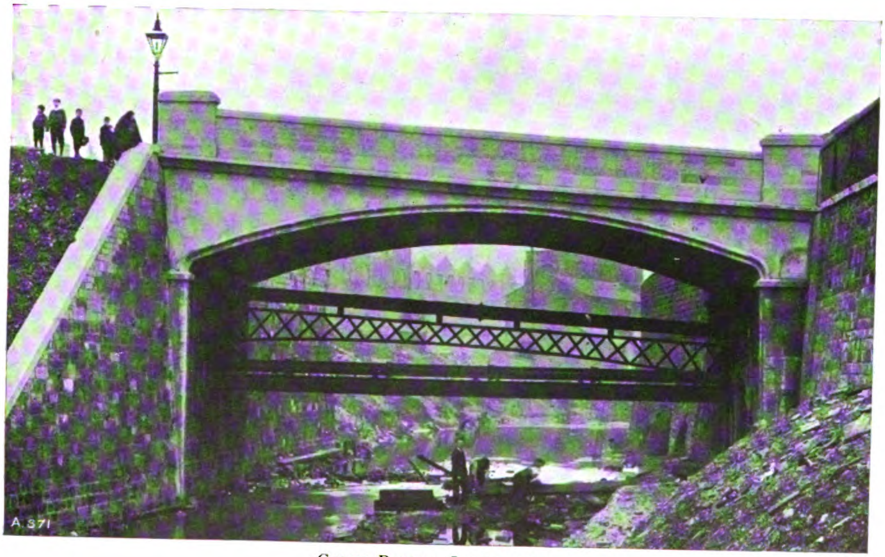


FIG. 9. DOWNSIDE ABBEY RESERVOIR
(General View during Construction).

THE NEW BRIDGE, COLNE.

As another example of reinforced concrete bridge construction on the Hennebique system we would illustrate the arch completed last year for the Corporation of Colne, Lancashire, from the designs of Mr. Hartley, the borough surveyor. The bridge has concrete foundations for the abutments. The arch itself is of reinforced concrete, and has the clear span of 45 ft. 6 in., the thickness being 10 in. at the crown and 14 in. at the haunches.



COLNE BRIDGE, LANCASHIRE.

THE BROOKLANDS MOTOR TRACK BRIDGE.

In continuation of our article on the above-named bridge in our July issue (No. 3, Vol. II.), we have pleasure in presenting two additional photographs of the finished structure, which have been put at our disposal by the contractors—*i.e.*, The Yorkshire Hennebique Contracting Co., Ltd., of Leeds.

It may be remembered that the bridge is built on 42 reinforced concrete piles, 22 ft. in length, and the superstructure consists of columns, bracings, arched beams and decking. The total length is about 200 ft., and the width 100 ft. The decking is bowl-shaped, and has a super-elevation of 25 ft., as will be seen from the illustration.

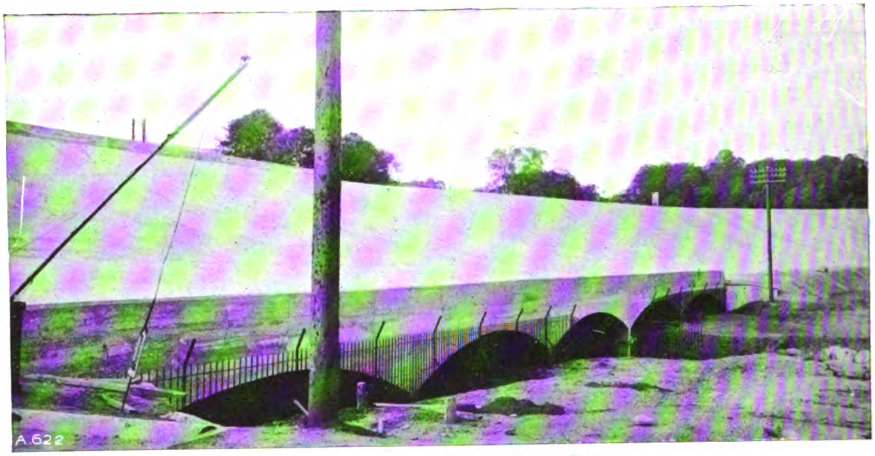


Fig. 10. Brooklands Motor Track Bridge (Front View).

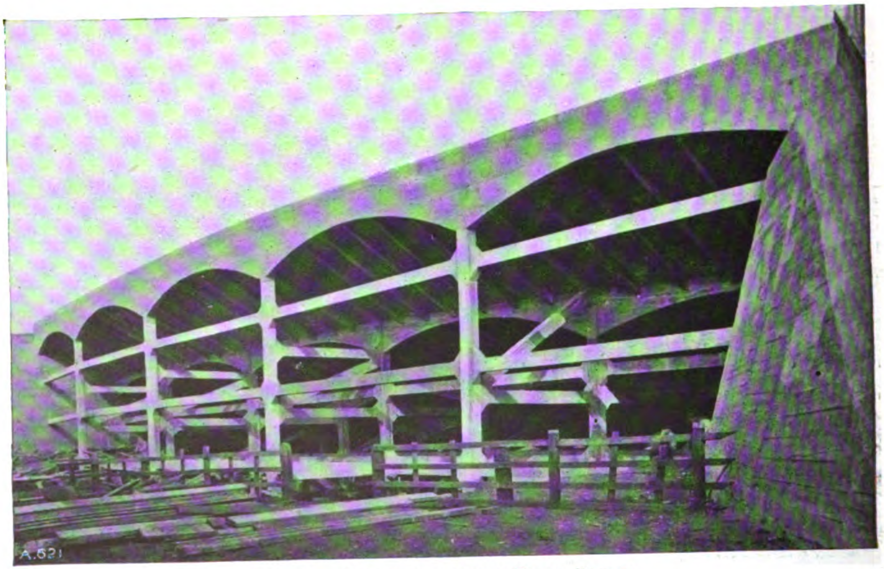


Fig. 11. Brooklands Motor Track Bridge (Back View).

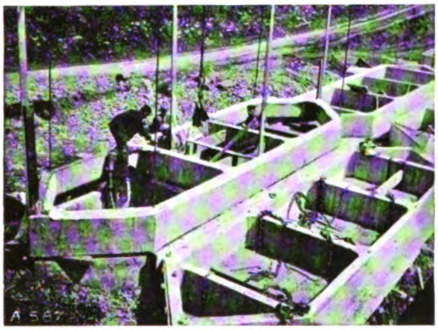
NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

REINFORCED CONCRETE CAISSONS.

When constructing the piers of the new bridge over the River Foyle, Messrs. Robert McAlpine and Sons adopted an entirely new method of sinking the foundations, which has been devised and patented by Mr. T. Malcolm McAlpine.

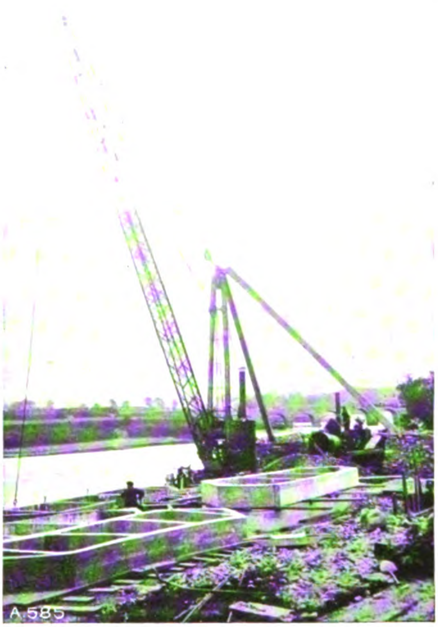


The bridge, which is quite ordinary, being of the lattice-girder type, has been constructed to carry the new Strabane and Letterkenny railway over the river Foyle, and was designed by Mr. James Barton, M.Inst.C.E., Messrs. Robert McAlpine and Sons acting as contractors.

When sinking the piers to the foundation level, the contractors, instead of using the metal caisson throughout, as is commonly done, or brickwork on a heavy iron curb, constructed the caissons entirely out of reinforced concrete, a plan which was entirely successful.

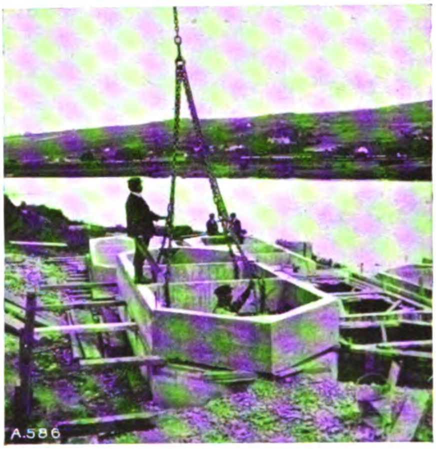
Messrs. McAlpine have kindly favoured us with the following particulars of the construction of the caissons:—

The entire caisson consists of a number of superimposed sections, the bottom of which has a cutting edge. These sections were made in moulds on the shore, and after being left for about four weeks to harden, were lifted bodily by a crane and lowered into place. Each successive section was kept in place by a series of vertical rods, which extended from the lowest section to above the surface of the water, thus ensuring each section resting plumb on the one below. The weight of each section was from seven to eight tons.



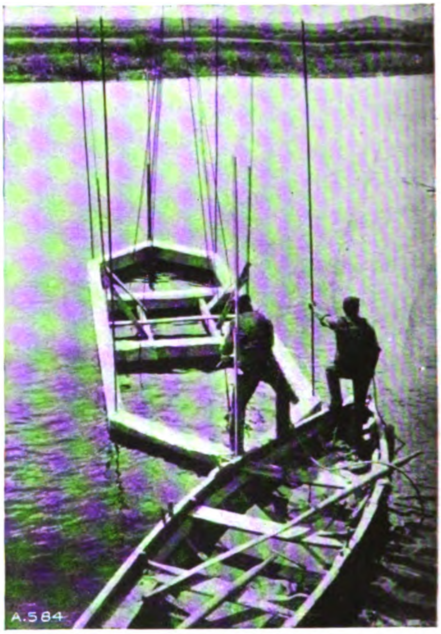
The concrete used consisted of four parts gravel to one of cement, which was reinforced by $\frac{5}{8}$ in. round bars.

In order that the joint between the successive sections should be satisfactory, a small groove was made in the upper surface of each, while the bottom of each section was provided with a small wedge-shaped projection. A roll of cement mortar enclosed in linen was placed in the groove mentioned, and as each fresh section was lowered into position, the projection, which dug into the soft mortar, made a perfectly watertight joint.


A.586

A.588

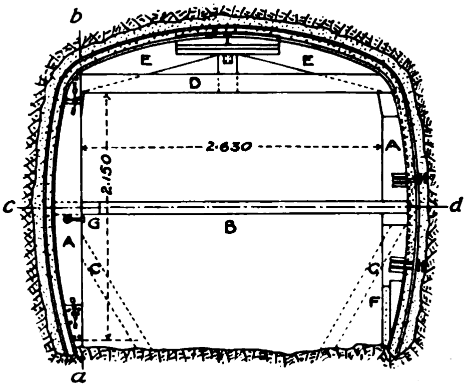
Neither staging, piling, nor hydraulic jacks were used in the construction of these foundations, and the cost of these reinforced concrete caissons worked out at about half the amount that would have been necessary to provide the more commonly used metal caissons.


A.584

REINFORCED CONCRETE IN MINES—MINE GALLERY REVETMENTS.

In our July issue reference was made to the employment of reinforced concrete in the United States as a substitute for the timbering of colliery workings. The same practice has been followed in some German coal mines, as mentioned in a previous issue, and we now give particulars of the manner in which the reinforced concrete has been applied in the collieries of the *Compagnie des Mines de Béthune,* Pas-de-Calais, France.

Some three years ago, owing to the scarcity of masons, the directors of this company found it would be impossible to complete the revetment of certain sections of the galleries within the required time, and decided to substitute for the usual construction — consisting of masonry piers, 0.5 metres thick, supporting steel I-beams—revetments in reinforced concrete only 0.15 metres thick. The advantage of the new departure which at that time appealed chiefly to the company was that the work could be executed by ordinary labourers under the direction of an experienced foreman mason.



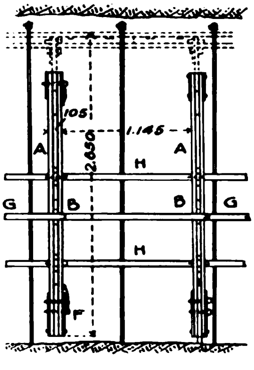
F.G. 1 (PART).

As the results attained were shown by subsequent experience to be quite satisfactory, the company decided to extend the employment of reinforced concrete to other parts of their mines, and by the commencement of the present year nearly one and a half miles of galleries had been treated with the same material.

The revetments are executed in sections 5 metres long by the aid of timber moulds. Fig. 1 contains an elevation and sections of the centering used for the construction of revetments in galleries measuring 2.60 metres high by 2.90 metres wide. Each section comprises ten panels of boards, 5 metres long by 35 mm. thick, supported by four frames spaced 1.25 metres apart, centre to centre. Each frame is formed of two uprights (A) separated by horizontal members (B), serving the purpose of distance pieces and cross-ties—or alternatively by two struts (C)—and by the crossbar (D) surmounted by the centering (E). Making-up pieces (F), pierced suitably with holes for the insertion of pins, and capable of sliding between the two uprights (A), permit the adjustment of the centering (E) to the required height, whatever may be the irregularities of the ground surface. The ends of the uprights and making-up pieces are sheathed in thin steel plate so as to protect the timber against abrasion and other injury.

In concreting a 5-metre section, the four frames (A) are first erected and spaced by using as templates two strips of steel (G) disposed horizontally and fixed half-way up the uprights on either side of the gallery. Behind the frames and at 75 mm. away from them are placed the metal bars for reinforcing the concrete afterwards to be deposited. The reinforcement consists of steel bars, 10 mm. sq., bent to the form of cross section of the gallery, and disposed normally to its axis in pairs, each pair of bars being spaced 80 cm. apart centre to centre, and connected by bolts passing through eye-holes formed at the termination of the curves. The bars are connected laterally by horizontal rods of 5 mm. diameter, spaced 23 cm. apart, centre to centre.

The correct disposition of the reinforcement is insured by four strips of timber (H) attached to the uprights, grooves of 10 mm. width being cut at the required distances apart in the inner surfaces of the timber to receive the bars.



SECTION ON a·b.
FIG. 1 (PART).

When the frames, the reinforcement, and two panels of shuttering at the base have been fixed in position, concreting is commenced, and the piers, as well as part of the arched roof, are progressively built up for the 5-metre section by moving the shuttering upward upon the frames after the concrete below has hardened.

Before executing the central portion of the arched roof, the two frames at one end are connected, close to the part where the revetment has so far been completed, by a rectangular timber frame (fig. 1) supporting the curved rib (I). Then half the space existing between the two main frames is filled with concrete, the centering (J) being placed upon the end frame and half of the rib (I). The remaining half of the space is filled in a similar manner. The roof is completed by depositing concrete between the remaining frames of the centering, each space being filled in two operations, as before.

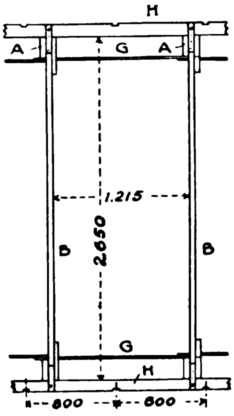


FIG. 1 (PART).

For workings of smaller dimensions, the general construction of the moulds and the method of executing the work are practically as described above.

In cases where it is desired to increase the solidity of a gallery passing through unstable earth, or in the vicinity of a junction, small tubes are embedded in the piers and in the arched roof, and through these tubes cement grout is injected, filling any fissures in the earth or any spaces existing between the other face of the concrete and the earth.

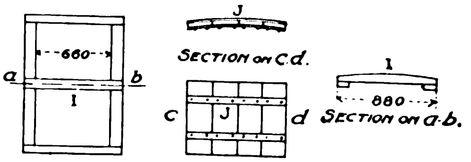


FIG. 2.

After removal of the moulds, the surfaces of the reinforced concrete are brushed down and rendered with a thin coating of cement mortar in the proportions of one part cement to two parts of fine sand.

For execution of the work, gangs of men have been organised who are able to complete a 5-metre section in 8½ hours, each gang consisting of five workmen and an experienced foreman.

The prime cost of the work per foot run is stated to be as follows:—

	s.	d.
Concrete (1·76 cub. metres)	1	8
Concrete-mixing (labour)		10
Reinforcement		7½
Cement	1	0¼
Concreting (labour)	2	0½
Centering (including maintenance)... ...		1¾
Total cost per foot run ...	6	4

This price is said to represent a saving of 40 per cent. upon that of lining the galleries by the ordinary method. The advantages obtained by the employment of reinforced concrete for the revetment of galleries have induced the *Mines de Béthune* to extend its application to the lining of pit shafts. In executing work of this kind, horizontal reinforcement consisting of rings of steel plate, 40 mm. by 10 mm., is first fixed in the shaft. The diameter of the rings is 8 cm. greater than the effective diameter of the shaft, the rings are spaced according to the solidity of the soil through which the shaft has been sunk, and they are connected one with another by four series of vertical ties in steel plate of the same cross section as that in the rings.

Concrete is deposited, in sections of four metres high, behind moulds formed of boards with grooved joints and braced to resist the pressure of the concrete. A platform from which the concrete is filled into the mould is suspended by four chains secured to a cable which is attached to a winding engine at the pit head, so that the position of the platform can be varied in accordance with requirements.

It is stated that the cost of lining colliery shafts with reinforced concrete is 35 per cent. less than that of the masonry lining previously adopted.

SPECIAL ARTICLES.

Under this heading we propose to present special contributions which reach us from time to time in connection with various subjects dealing directly and indirectly with concrete and reinforced concrete.—ED.

ON THE VALUE OF GAUGED NEAT PORTLAND CEMENT.

By E. P. WELLS.

A FEW years ago I carried out a large number of experiments with Portland cement that had been ground down to flour to ascertain the value of the same as compared with the cement as received, also the extraction of the residues and the regrinding of the same to flour. My experiments were made solely with Portland stone as an aggregate and the sand obtained from the ground stone. For sand briquettes the Portland stone was passed through the 20 x 20 and retained on the 30 x 30 sieve, where the sand was used for making concrete cubes the same varied from ⅛″ down to flour in fineness. In the results of my experiments with old gauged cement the above Portland stone or oolite was used solely for both 3 to 1 briquettes and concrete. The amount of water used in making the 3 to 1 oolite briquettes was 12 per cent. owing to the oolite sand absorbing so much moisture. In making the concrete the stones were soaked in water (the absorption being from 8 to 10 per cent.), the sand and cement was mixed dry, then the wetted stones were added, the total quantity of water used, including the amount absorbed by the stone, being about 14 per cent.

In the year 1902 I had the means at my disposal to readily grind cement down to flour and to extract the same by means of Goreham's Standard Flourometer, a most tedious operation, when it is taken into account that it took nearly one month to obtain 10 lb. of flour cement. Whilst my experiments as to the value of flour cement were being carried out it was suggested that I should see if any strength could be obtained out of old gauged neat cement. Unless otherwise stated all the following results were obtained from the old gauged cement ground down to flour and extracted from the residues by means of Goreham's Flourometer, the residues were ground and flour extracted until no residue remained.

No. 1.—My first experiment was conducted with neat briquettes made March 27th, broken in May, and ground up to nil on a 200 x 200 on November 26th, 1901. The percentage of residue for the original cement being 1½ per cent. on a 76 x 76 sieve. The 3 to 1 oolite briquettes gave the following results (1 day in air and the remainder in water):—

28 days old, 110 lb. per sq. in. of sectional area; 2 months old, 195 lb. per sq. in. of sectional area; 3 months old, 220 lb. per sq. in. of sectional area.

No. 2.—When ground wholly to flour the following results were obtained:—

3 to 1, 105 lb. at 28 days; 3 to 1, 145 lb. at 2 months.

A small cube of 5 to 1 concrete, 72·50 mm. square, and composed of 4 parts stone, 1 part sand, 1 part cement, all by weight, crushed at 28 days, gave 37·32 tons per sq. ft.

The above when made were very slow-setting and it was with great difficulty that the briquettes and cube were taken from the moulds 24 hours after being made.

As these results were extremely satisfactory, I next turned my attention to the reburning of the gauged neat cement in an open fire and for several periods of time.

Experiment No. 1.—The cube was burned for 1 hour, ground to flour, and the following are the results of the 3 to 1 briquettes (the residue in the original cement being 1½ per cent. on the 76 x 76 sieve):—7 days old, 130 lb. per sq. in. and 265 lb.; 28 days, 335 lb.; 2 months, 355 lb.; and 5 months and 1 week, 405, 405 and 430 lb.

Experiment No. 2.—Briquettes burnt for 2 hours. 7 days, 140 lb.; 28 days, 275 lb.; 2 months, 360 and 385 lb.; and 5 months and 4 days, 475 and 450 lb. per sq. in.

Experiment No. 3.—Three hours' burning. 7 days, 205 lb.; 28 days, 405 and 395 lb.: 2 months, 435 and 370 lb.; and 5 months and 2 days, 450 and 430 lb. per sq. in.

Experiment No. 4.—The residues obtained from some of the cement not ground to flour of the 1, 2 and 3 hours' burning were reground to flour with the following results:—7 days, 225 lb.; 28 days, 425, 415 and 455 lb. per sq. in.

This last experiment gave a better result than the original cement when mixed 3 to 1 and tested for the same periods.

Experiment No. 5.—The briquettes were burnt in a fierce fire and were partially clinkered, and the results show a marked falling off in strength. 28 days, 170 and 165 lb.; 52 days, 185 and 155 lb. per sq. in.

Experiment No. 6.—Five hours' burning, briquettes partially clinkered. 28 days, 125 and 145 lb.; 51 days, 140 and 135 lb. per sq. in.

Experiment No. 7.—Six hours' burning, briquettes partially clinkered. All 51 days old. 200, 210 and 250 lb. per sq. in.

The above experiments clearly demonstrate that old gauged cement, if burnt in a slow fire and not partially clinkered, is about equal to the cement before the same had been gauged, but reclinkering kills its properties. The setting action was in all cases very rapid; the briquettes set hard in less than 5 minutes.

Experiment No. 8.—Made from gauged rotatory cement, 3 to 1, 2 months old, as before, but the briquettes not burnt. This cement only contained, before gauging, about 36 per cent. of flour, so that the residues were abnormal, and the results obtained exceptionally good. 28 days, 395, 360 and 360 lb. per sq. in. The following are the tests of the 3 to 1 briquettes, made with the cement as originally received:—12 days, 250 lb.: 42 days, 485 and 525 lb. per sq. in., so that the old gauged briquettes reground to flour were practically as good as the cement before being gauged.

Experiment No. 9.—Rotatory cement reburnt and clinkered. All 28 days, 115, 120 and 85 lb. per sq. in. See experiments 5, 6 and 7.

One briquette (3 to 1) made from residues which had passed through a 200×200 sieve was blown badly after being 4 days in water. This is very peculiar, as there was no gypsum in the original cement.

All the briquettes when broken were a bright olive green in colour owing, no doubt, to the amount of sulphur which had been taken up by the neat briquettes being burnt in a coal fire, and upon analysis this amounted to 0·48 per cent.; there was no alteration otherwise in the chemical analysis of the cement.

Experiment No. 10. — Neat gauged briquettes, 7 days in water, then burnt in a slow fire and reground to nil on a 100 × 100 sieve.

3 to 1 briquettes, 28 days old, 245 and 285 lb. per sq. in.

5 to 1 concrete, 28 days old, proportions as before, crushed at 62·28 and 74·65 tons per sq. ft. A further experiment, the gauged cement being ground to flour and not burnt, gave the following results (3 to 1, as before): —330, 325 and 310 lb. per sq. in., and 1 briquette, made with residues, nil on 200×200, 28 days old, broke at 265 lb. per sq. in.

It will now be interesting to compare these results with the original cement before being gauged and reburnt. 7 days neats, 525 and 855 lb.: 28 days, 815, 895, 910 and 900 lb. per sq. in.

3 to 1, 7 days, 325, 325 and 320 lb.; 3 to 1, 28 days, 375, 405 and 470 lb. Neat crushing, 7-day tests, 302·76 tons sq. ft.; 28-day tests, 452·07 tons sq. ft.; 4 months tests, 676·04 tons sq. ft.

5 to 1 concrete (in air):—

7 days, crushing 103·68 tons sq. ft.; 14 days, 138·94 tons sq. ft.; 21 days, 147·23 tons sq. ft.; 28 days, 150·04 tons sq. ft.; 35 days, 153·45 tons sq. ft.; 42 days, 161·75 tons sq. ft.

Comparing the 28-day results it will be observed that the concrete made from the reground cement was nearly half the strength. If the gauged cement had been kept in water for a period of 6 months the result, after regrinding, would, I think, have shown a great falling off in strength, as immersion in water for only 6 days has very little effect on the residues in a neat cement.

Experiment No. 11.—This is the only experiment that I made with neats from old gauged cement, owing to the fact that it required such a lengthy period to grind sufficient cement for the purpose with the small mill at my disposal. The gauged cement was the same age and of the same manufacture as stated in experiment No. 10.

Neat briquettes, 28 days old, ground to nil on 100×100, 315 lb. sq. in.

Neat briquettes, ground to flour and 28 days old, 315, 340 and 285 lb. per sq. in. See results 3 to 1 at 28 days old, 330, 325 and 210 lb. per sq. in.

A cube of neat 72·5 mm. sq. at 28 days crushed at 62·21 tons per sq. ft., a little less than 1-7th of the origiinal cement, not one-half the strength of the 5 to 1 concrete, and even less than concrete (5 to 1) made from the gauged cement reburnt—viz., 62·28 and 74·65 tons per sq. ft.

The natural conclusion that my readers will come to is that in all these experiments the strength of the old gauged cement was in the residues, and that if the flour were experimented with, no result, or very little if any strength, would be obtained. This was my opinion and that of all those with whom I was in active correspondence during the period over which my experiments extended, but the following experiment, No. 12, clearly shows that we were all in error.

The flour cement was made into neat cubes, 72·5 mm., kept in water for 28 days, then dried before a fire and reground to flour, when the following result was obtained for a 3 to 1 briquette:—28 days old, 265 lb. sq. in. Gauged flour cement, which had been burnt in a slow fire and which was ground nearly to flour with a trowel, gave for 3 to 1 at 28 days, 290, 310, 310 and 325 lb. per sq. in. A small piece of the burnt cube, which had clinkered, was ground to flour, and the 3 to 1 at 28 days broke at 265 lb.

This experiment demonstrates that clinkering does not weaken the gauged cement to the same extent when made from flour cement as when the residues are present. The colour of this flour cement after being burnt resembled curry powder.

My last experiment was only concluded the middle of last January. About 5 years ago a slab of neat cement was given me that had been immersed in water for 7 years, and during the time it was in my possession was generally kept in a warm room on the mantelpiece. Through the kindness of a friend who crushed the specimen, ground the same to flour and made two 3 to 1 oolite briquettes I am much indebted. The following results were obtained:—Crushing of the 12-years old neat cement, 817 tons per sq. ft., the specimen being 2″ × 1½″ × 1″ deep, had the cement been made into a 72·5 mm. cube there is no doubt the crushing result would have been much lower. 3 to 1 briquettes, 28 days old, 25 days in water, 210 and 210 lb. per sq. in. Age has evidently made very little difference, when the gauged cement is ground to flour and made into 3 to 1 briquettes. I am not in a position to state what amount of residue there was in this old gauged cement as no record is in existence, but judging from the cement from the same makers, sent me for experimental purposes in 1902, should say a very coarsely-ground cement. The 1902 cement gave 72 per cent. residue, 28 per cent. flour cement, 10 per cent. on a 76 and 19 per cent. on a 100 × 100 sieve. The following tests of this cement are interesting and bear out my contention, which is well known, that if good concrete is to be obtained the cement must be finely ground and well burnt.

(1) 3 to 1 oolite briquettes made with the cement as received, all 28 days old. Average of 10 briquettes, 221½ lb. per sq. in.; highest, 245; lowest, 200 lb. sq. in.

(2) 3 to 1, as before, the cement being reground to nil on a 100 × 100 sieve. Average of 10 briquettes, 422½ lb. per sq. in.; highest, 470; lowest, 390 lb. sq. in.

(3) 3 to 1, as before, cement passed through a 200 × 200 sieve, the residue being rejected. Average of 10 briquettes, 465 lb. per sq. in.; highest, 510; lowest, 380 lb. sq. in.

(4) 3 to 1, as before, made with flour cement. Average of 10 briquettes, 491 lb. per sq. in.; highest, 570; lowest, 420 lb. per sq. in.

(5) 3 to 1, as before, made with flour cement, obtained from regrinding the residues, the original flour being rejected. Average of 20 briquettes, 581½lb. per sq. in.; highest, 635; lowest, 540 lb. sq. in.

(6) 3 to 1, as last, but kept in air for 3 months, broke at 950 lb. per sq. in.

In comparing the 3 to 1 briquettes (4) made with flour, with the old gauged cement ground to flour, and the same age—viz., 28 days—the strength is a little less than one-half, but exactly one-half of the lowest test at that period—viz., 420 lb.

The results are, in my opinion, very satisfactory indeed, as they clearly show that the mere gauging of Portland cement with water does not very materially reduce its strength if the same is reburnt and reground within a short space of time, but if the gauged cement is partially clinkered then there is a great falling off in strength. It is the practice with many cement manufacturers to use their old briquettes, grinding the same with the clinker, but if this practice is continued I should advise them to reburn in a very slow fire before regrinding, and there is no reason if this is done why old gauged briquettes should not be used. They are infinitely stronger when burnt than an underburnt cement and much safer to use.

After being reburnt the gauged cement sets very rapidly, but where the gauged cement is not burnt the setting is very slow indeed.

I should like, if I could, to carry these experiments over a period of years, gauging and reburning and gauging and reburning to see whether it is possible to absolutely destroy its setting action.

I should like some expert to take up the matter in his leisure time and give the benefit of his experience, not only as to chemical tests, but also the physical tests. It was a source of much pleasure when I made all these tests, which, unfortunately, were broken off, and I have not had the time since to go more fully into the matter, but I trust that the readers of your valuable paper may be interested in what I have written.

E. P. Wells.

INDUSTRIAL NOTES.

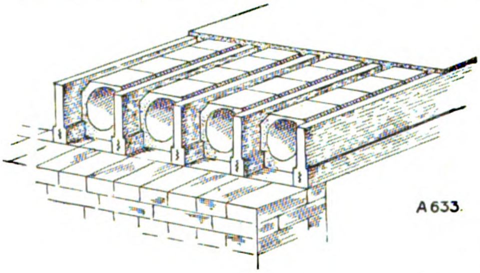
These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

MODERN "ARMOURED TUBULAR" FLOORS.

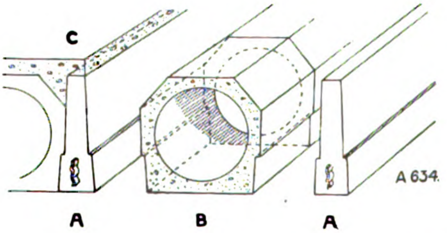
By E. v. MANDELSLOH.

THE ARMOURED TUBULAR FLOORING CO., LTD. 53, Victoria Street, Westminster, S.W., have started at their works, 56a, Leighton Road, Kentish Town, the manufacture of an armoured concrete floor, which, owing to its many advantages over other concrete and reinforced concrete floors should commend itself to architects.

As shown on the section, the floor consists of concrete webs, in the lower part of which a flat steel reinforcement bar of special design is embedded, and of hollow tubes of 8 in. in length, made of concrete composed of ash and cement, the whole construction being completed by spreading a layer of concrete on top. The so-called webs and tubes are made at the factory, and are consequently set when used in the building.



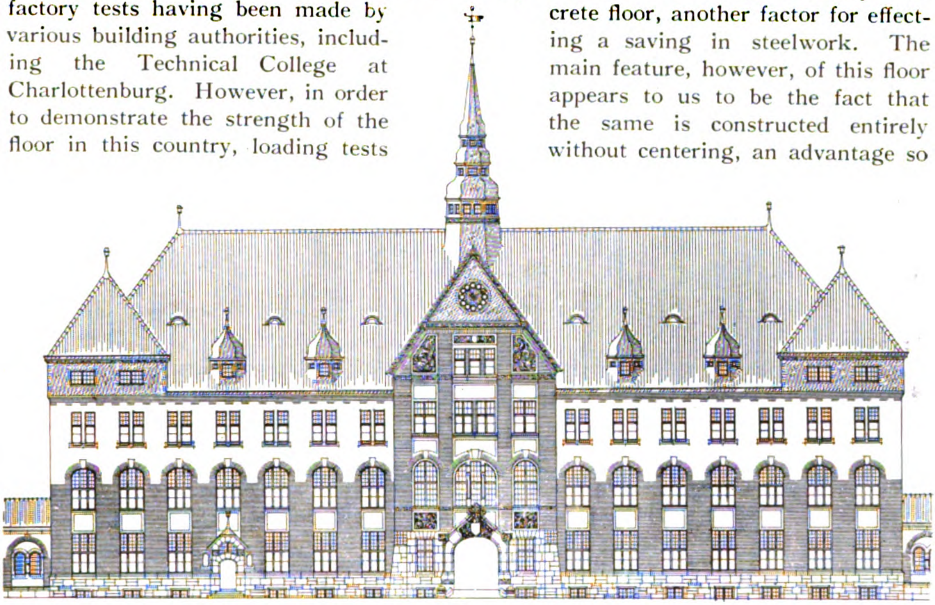
A 633.



A 634.

Owing to the small quantity of steel reinforcement which is completely imbedded in the concrete webs, and owing to the fire-resisting qualities of all materials employed, this floor is rendered absolutely fire-resisting, which is often pretended, but to our knowledge is not the case, with any other construction of concrete flooring. The floor, which was tested by fire last January at the Testing Station of the British Fire Prevention Committee, was exposed to a fire of four hours' duration, the temperature rising to 2,200 degrees Fahr., followed by the application of water for five minutes, and loaded with 280 lbs. per sq. ft. The application of water produced no effect beyond eroding some of the plaster on the soffit where struck by the jet, but neither fire nor water passed through the floor, the deflection being only 7-16 in. It attained the highest classification of "full protection" obtainable, and we understand that the above is one of the most successful results obtained in official tests with a reinforced concrete floor, and it should be pointed out that the floor tested would probably stand a second test if it had to undergo the ordeal.

The Armoured Tubular Floor is a novelty in this country, but for some time has enjoyed a good reputation abroad and has been used in Germany, in which country alone more than a million sq. yds. of same have been laid during the last two years. We have before us testimonials testifying to the good qualities of the floor from such authorities as Dr. Fritz von Emperger, Vienna; W. Knapp, Professor of the Technical College, Darmstadt; Dr. Mueller-Breslau, Director of the Technical College, Charlottenburg, and E. Dieckmann, Director Royal Building School, Barmen.

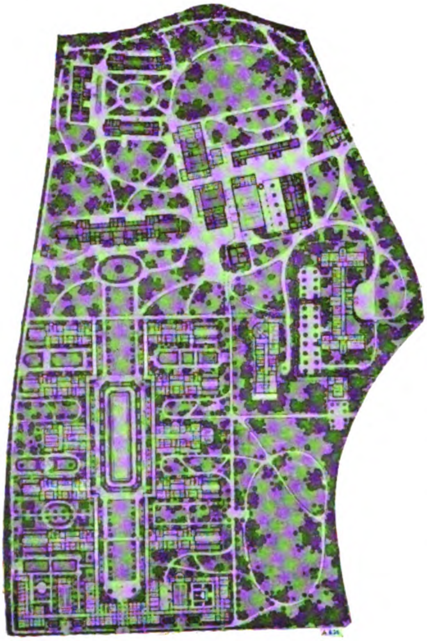


FRONT ELEVATION OF PART OF THE NEW MUNICIPAL HOSPITAL, COLOGNE. A635

The carrying capacity of the floor is proved beyond any doubt, numerous satisfactory tests having been made by various building authorities, including the Technical College at Charlottenburg. However, in order to demonstrate the strength of the floor in this country, loading tests were recently held at the Testing Station of the British Fire Prevention Committee, one strip of flooring of 2 ft. 6 in. width, and of a free span of 14 ft., which was constructed to carry 1½ cwt. per sq. ft., with a safety factor of 4, reaching the breaking point at a load of more than 12 cwt. per sq. ft.; another strip of 2 ft. 9 in. width, of the phenomenal span of 28 ft., constructed to carry 1 cwt. per sq. ft., with a safety factor of 4, was unbroken at a load of 7½ cwt. per sq. ft. The results in both cases are certainly quite exceptional.

The possibility of constructing a fire-resisting concrete floor in any spans up to 30 ft. without the use of any intermediate steel work or columns and stanchions, should draw the attention of architects, the saving effected by the omission of all steelwork, with the exception of main girders, being a very considerable one. The hollow tubes render the floor sound proof, and form a good insulator against heat or cold; the tubes can also be utilised as conduits for pipes and electric wires. The weight of the Armoured Tubular Floor is only one half that of the ordinary concrete floor, another factor for effecting a saving in steelwork. The main feature, however, of this floor appears to us to be the fact that the same is constructed entirely without centering, an advantage so obvious that it is needless to dwell upon same. The simplicity of the construction ensures great rapidity in the erection of the floor. The metal reinforcement is such as to allow of the additional advantage of a mechanical bond, beyond that of ordinary adhesion.

The Armoured Tubular Floor has been used in magnificent buildings all over Germany, in which country concrete constructions are so much in vogue. All classes of buildings have been constructed with this floor, such as office buildings, flats, warehouses, factories, hospitals, schools, post offices, and other Government and municipal buildings. We present a plan of the newly-erected municipal hospital buildings, Lindenburg, at Cologne, Germany, in which building the enormous quantity of about 30,000 sq. yds.



SITE PLAN OF THE NEW MUNICIPAL HOSPITAL, COLOGNE.

of Armoured Tubular Flooring has been laid in various spans, several of the large hospital rooms being fitted with floors of a span of 30 ft. without intermediate steelwork. A new administration building of the State Railways is now in course of construction next to the Central Station at Cologne, in which about 12,000 sq. yds. of the Armoured Tubular Flooring will be used.

Within the first six months of its introduction, no less than fifty-one new buildings were constructed with this flooring in Berlin alone.

Apart from the fact that the Armoured Tubular Floor compares very favourably as to price with the ordinary or any other system of concrete flooring, its many advantages over other systems should soon gain it in this country the same popularity which it enjoys abroad. The new building of the Humber cycle and motor works and offices at Coventry, now in course of construction, is being fitted with Armoured Tubular Flooring, the area of flooring being about 6,000 sq. yds.

MUNICIPAL HOSPITAL, COLOGNE
(In course of construction).

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume II. No. 5. NOVEMBER, 1907.

EDITORIAL NOTES.

THE LOCAL GOVERNMENT BOARD AND REINFORCED CONCRETE.

THE feeling still seems to be great in certain districts regarding the Local Government Board's attitude in insisting on much restricted loan periods for public works in reinforced concrete, compared with those granted where older methods of construction are applied. The feeling is not unnaturally accentuated by the announcements made during last session of the House of Commons by the representative Ministers for our great spending departments, such as H.M. Office of Works, the Admiralty and the War Office, by all of whom reinforced concrete has been adopted.

The point that has most specially raised comment is the statement of the First Commissioner of Works, that the saving effected by the use of reinforced concrete in Post Office buildings is 20 per cent., for a saving of this extent would, of course, be a most important matter in municipal work of all kinds.

VIEWS OF THE CEMENT TRADE.

A new feature in the question appears also to be a feeling of soreness in the cement trade that the use of reinforced concrete by municipalities should be handicapped by the action of the Local Government Board, while other public departments are successfully utilising this material, and we observe that in his annual address to the shareholders of the Associated Portland Cement Manufacturers (1900), Ltd., the chairman, Mr. F. A. White, referred to this matter in the following terms, which, while much to the point, leave nothing to be desired in the way of courtesy.

Mr. White at the annual meeting said:—

> "Would it be believed in Germany, for instance, that in this country, while the First Commissioner of Works, the Secretary of State for War and the Civil Lord of the Admiralty has each in his place in Parliament praised reinforced concrete as both efficient and economical, and given instances of its successful use in the last three years under his department; nevertheless, the Local Government Board penalises its use throughout the municipalities of the country by refusing to sanction loans on buildings or works so constructed unless they are made repayable in fifteen years, instead of allowing them to run over thirty years, as in the case of brick constructions! And yet such is the case. The New Post Office in London is being built entirely in reinforced concrete at a saving of 20 per cent. It has been largely used at Woolwich Dockyard and Arsenal, and the Admiralty uses it for floors, jetties, and the like, and finds the costs of their maintenance greatly reduced. Either this should not be, or municipalities should receive every facility for equally economical construction, and should surely not be financially hampered for following the example of the great spending departments of the State. We know that the wrong sort of conservatism always has at last to give way. I venture to suggest that this conservatism would be considered to be of the wrong sort by the President of the Local

> Government Board himself; and though I might not in all cases have the honour to find myself in agreement with that right honourable gentleman on such a point, I should not be surprised to learn that he did not disdain to be in agreement with me on this one. In fact, I incline to wonder whether the authorship of the restrictions to which I have referred is rightly—however it may be technically—laid at his door."

We, of course, sympathise in every way with the feeling of the cement manufacturers in a matter of this kind, more particularly as the Portland Cement industry requires every encouragement in this country.

A POSSIBLE COMPROMISE.

As we have indicated before, we realise that perhaps for the present the best compromise that could be arranged is that the Local Government Board, whilst retaining its 15-years loan period for reinforced concrete structures, when put before them in the paper stage, should consent to extend that period to the usual period allowed for brick structures when the work is completed—*i.e.*, after that time has elapsed which we believe is held by the officials of the Local Government Board to be the critical one—namely, the period of construction and "setting."

We feel sure that now the President of the Board has had an opportunity of visiting France and Germany, and seeing the numerous important municipal structures erected so economically in reinforced concrete in all parts of those countries, he will be more inclined to save the pocket of the ratepayer, and also avoid handicapping a great national industry.

FICTITIOUS PORTLAND CEMENT.

WE have frequently referred to the menace of fictitious Portland cement sold in this country and in our colonies as British "Portland" cement, whilst in reality nothing more than an unreliable natural cement imported from Belgium.

This fraudulent sale of "Portland" cement, which is frequently carried on under fictitious or counterfeit labels, and in packages similar to those used by our leading British makers, is a source of grave danger to all cement users. But it is a particularly serious matter to those engaged in reinforced concrete work, and thus every effort should be made to put a stop to this fraudulent practice. So dangerous has this scandal become, for reinforced concrete in particular, that it is to be hoped that arrangements will shortly be completed to treat the sale of cement under wrongful label as a criminal offence, for we hold that the endangering of life and limb by unscrupulous purveyors of structural materials is just as vicious as the endangering of life and health by the sale of fictitious drugs, unhealthy food and the like.

Civil cases there have of course been, not only here but in our colonies, and a notable instance was the one recently successfully conducted at Malta, to which we have already referred in a former issue.

But to our mind this is not, as a rule, a question merely for civil proceedings, but of the application of the criminal code, for architects, engineers, contractors, workmen and the public generally must be protected from becoming unwitting victims of this obtaining of money under false pretences.

As we have indicated, the fictitious Portland cement primarily hails from Belgium, and comprises a "Natural" cement of utter unreliability. Thus it is fortunate for Great Britain that we have so able a Consular representative in that country, who not only, year by year, points out the existing state of affairs—namely, the export from Belgium of cement with misleading labels—but who has assisted generally in the endeavour to restrict the scandal.

FICTITIOUS CEMENT AND THE BELGIAN CONSULAR REPORTS.

We have, as a matter of fact, again before us a report by Sir Cecil Hertslet, the Consul-General for Belgium, issued September, 1907, and ranging for the eighteen months ending June 30th, 1907.

As in the report published for 1906, considerable space is devoted to the cement question, and we think we cannot do better than print some parts of the report, as they certainly speak for themselves.

Sir Cecil Hertslet writes:—

> ". . . Were it not that I should be guilty of repetition, attention might again be called to the systematic habits of the dealers in Belgian cement in passing off their productions of inferior quality as an article of British manufacture or British origin at exceptionally low prices, which cannot be approached by makers in the United Kingdom as long as they retain the high standard for which British cement has been, and still is, famous.
>
> "It is manifestly unfair to the maker in the United Kingdom that Belgian cement can be sent to the British Isles, the Colonies and foreign countries, in the enormous quantities which it is, bearing descriptions and labels in English, the obvious intention of which is to encourage the supposition that the article sold is British made.
>
> "The blame cannot be put so much upon the manufacturers themselves as upon the commission agents, and dealers of that class, who furnish any labels that may be required to the makers to attach to the barrels or casks when forwarded from the works, many of which labels are, without doubt, infringements of trade-marks or makers in the United Kingdom. Persons who purchase Belgian cement are also open to criticism, provided that they dispose of it to credulous buyers with British labels attached.
>
> "Many Belgian commission agents are aware of the risks they run in shipping cheap Belgian cement bearing labels which are registered trade-marks of British firms. With vigilance such measures can be arrested, but it is difficult for the British manufacturer to trace the fraudulent imitations which are being passed off under his particular brand in the Colonies and foreign countries."

Nothing could be clearer than this indictment by so well-known an authority.

THE GRADUAL REDUCTION OF THE AMOUNTS OF BELGIAN CEMENT USED AT HOME AND IN OUR COLONIES.

Another part of the report of our Belgian Consul-General gives some encouraging statistics showing how the export of Belgian cement into Great Britain and the Colonies is being reduced. Great Britain, which for many years has been the largest buyer of Belgian cement in the world, fortunately no longer occupies that unenviable position.

The falling off for last year was as much as 45,309 tons as far as the United Kingdom is concerned, and by way of comparison there has also been a very considerable falling off for the first half year of 1907 as compared with the first half year of 1906, the difference between the two half years showing a reduction of 30,000 tons.

Although the Colonies and Imperial Possessions, unfortunately, still take a large quantity of this unreliable material, notably Australia, Canada, Cape Colony, India, Natal and Straits Settlements, yet we observe with pleasure that the quantity used in those parts of the world has also decreased in every case, and that in some instances the decrease has been considerable.

We observe at this point that Egypt, however, is still using a very large amount of this material—*i.e.*, to the extent of some 37,000 tons last year—and it is to be hoped that the British engineers and architects holding Government appointments in that country will soon more fully realise its unreliability for public works. It would indeed be regrettable if any of this extraordinary Belgian material found its way into the great sanitary works and public structures under contemplation for Cairo.

As far as the Colonies are concerned, the Consul-General states that "it is difficult to explain the lesser demand from British Possessions for Belgian cement, unless it is that buyers are beginning to realise that much of the cement manufactured in Belgium, bearing British marks and brands, is not the genuine article, but is in every sense inferior to the British production—*i.e.*, in many cases is not entitled to be called 'Portland' cement at all according to the accepted standard." We concur that our Colonies are also gradually awakening to the danger.

It is to be hoped that our Consul-General's work in Belgium in matters pertaining to cement will continue to throw light upon the devious methods of certain cement makers and purveyors, and that his efforts will bear good fruit, so that the coming twelve months may show a still further decrease in the use of Belgian cement, not only in this country but in the Colonies and Imperial Possessions.

STANDARD NOTATION FOR REINFORCED CONCRETE BEAM FORMULÆ.

IN an article printed early this year* the excellent suggestion was made by M. de Tedesco that existing methods of calculation differing principally in algebraical forms, symbols, and co-efficients might without serious difficulty be translated or transposed and written with generally used symbols so as to leave only one method for each country.

Doubtless it would be possible by means of influential bodies like the French Commission du Ciment Armé, the Joint Committee inaugurated by the American Society of Civil Engineers, and our Engineering Standards Committee to formulate official standard methods of calculation for each country concerned. Further, it would be possible, although far more difficult, for some such body as the International Commission on Reinforced Concrete to arrive at standard methods of a universal character.

But at the present time it does not seem probable that the various scientists and engineers who are engaged respectively in the theoretical study, and the practical application of reinforced concrete would be prepared to sink their differences on points of detail, and to find in any common group of algebraical equations an adequate expression of their personal views and experiences.

In Great Britain, on the Continent, and in the United States, scientists are divided by divergent views concerning the treatment of concrete in tension and the relative merits of the "straight line" and the "parabolic" stress-strain curves, while various practical engineers manifest strong partiality for empirical rules which are based on actual experience, and have been proved reliable by the test of time.

---

* Vol. II., No. 1, p. 52.

These circumstances suggest the difficulty of arriving at any general agreement in respect of national standards of computation, and the different modes of thought and expression in different countries seem to make an international standard still more difficult of attainment.

The most hopeful sign of progress in this direction is the adoption of the "straight-line" theory by the Prussian Government, the French Commission du Ciment Armé, and other authorities on the Continent, by many leading writers and engineers in the United States and Canada, and by the British Reinforced Concrete Committee, which recently completed its labours.

Unfortunately, it happens that even this approach to uniformity is marred by the divergent algebraical forms in which the theory is set forth, and the Babel-like confusion existing in respect of the symbols by which the necessary factors are represented.

STANDARDISATION OF ALGEBRAICAL SYMBOLS.

While thoroughly sympathising with the suggestion made by M. de Tedesco, and hoping that it will be realised before many years have passed, we believe that for the moment the most useful direction for concerted effort is towards the standardisation of algebraical symbols employed in formulæ for the design of reinforced concrete structures.

The engineer who desires to acquire knowledge or additional knowledge does not mind reading and comparing different theories and their resultant formulæ, but is probably annoyed to find that for every individual theory and every series of rules a new vocabulary must be committed to memory.

The fact is that, with few exceptions, authors and authorities have adopted piecemeal notation, giving no thought to anything but their momentary and local needs, and disregarding many symbols which have long been used in engineering practice, and have thereby acquired definite associations. Thus there has grown up a tangle of notations based upon no central idea or system, and wherein many of the symbols are mutually inconsistent or without any self-evident recommendation.

THE COLLAPSE OF THE QUEBEC STEEL BRIDGE.

It may be recollected that we have occasionally referred to the technical detail of failures with reinforced concrete, such failures having almost invariably occurred during construction, and mainly through the negligence of individuals.

Whilst dealing with such accidents ourselves in a technical manner we have, much to our amazement, observed the great prominence accorded them by the daily press, though of such small importance compared with other failures in building construction. In fact, the daily press has of late rarely given the same notice or space to accidents occurring, say, in a steel structure, as to one in a reinforced concrete building.

This peculiarity has more particularly been brought home to us during the last months, when the greatest collapse of a steel structure that the world has ever known, took place at Quebec, involving not only over seventy deaths and a long list of injured, but also an enormous loss in material, labour, and in money—*i.e.*, some £500,000, and some 40,000 tons of fitted steel.

Regardless of the exceptional character of this disaster, the like of which has never been equalled during a building operation, the amount of space devoted to the accident in the majority of the daily papers has not been greater (indeed, frequently less), than that devoted to, say, a collapse of some small part of a reinforced concrete building involving no loss of life or at the most a few lives and perhaps £1,000 to £5,000 in money value.

We are quite at a loss to account for this phenomenon, and can only assume that accidents are considered so frequent an occurrence in steel construction that the press has become callous of them, whilst accidents of minor importance with a *new* material awaken special interest.

We think the daily press would do better, not only in respect to a modern form of construction like reinforced concrete, but with respect to many other materials or systems introduced for new works, to at least place any hitch or accident occurring, in its proper relationship to other similar accidents with better known methods of construction.

THE FIRE OFFICES AND REINFORCED CONCRETE.

Our readers will be pleased to observe that thinner reinforced concrete walls than heretofore are now at least permissible, in certain classes of buildings known as Standard III. and Standard IV. under the Fire Office rules.

Thus in this class of structure 5-in. walls are now permissible, and the rule recently issued reads:—

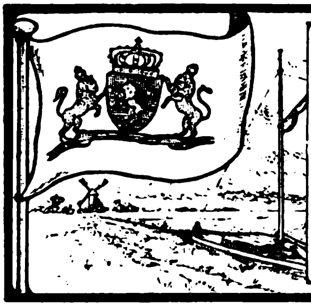
> "External walls of reinforced concrete, not less than 5 in. thick, but conforming in other respects to the Rules for Standard Fire-Resisting Buildings, are allowed between piers and for main supports."

There are two points we should, however, like to call attention to in respect to the Fire Office Rules, and they are in the form of queries:—

Why should the Fire Offices Committee generally speak of "Cement" concrete, when what they mean is "Portland Cement" concrete? Surely a cement concrete in which Natural Belgian cement were used would be a source of extra risk requiring an additional rating.

Further, why should the Fire Offices in their recent rules still adhere to the British Standard Specification for Portland cement of December, 1904? An addenda slip referring to the Standards of 1907 is required.

Lastly, why should the rules on Reinforced Concrete be entitled "Rules as to Ferro-Concrete or Reinforced Concrete Construction"? "Reinforced Concrete" is the general description for the material dealt with, and this term has been adopted by the Royal Institute of British Architects in its recent Report. If the term "ferro concrete" is used, why not "armoured concrete" or "concrete steel," or any of the other fancy descriptions.



THE HISTORICAL EVOLUTION OF REINFORCED CONCRETE IN HOLLAND.

By S. J. RUTGERS, C.E., Rotterdam.

(Translated from the Dutch.)

We have previously dealt with the Historical Evolution of Reinforced Concrete in various countries, in France, Germany, Austria, Italy and Switzerland, and we are continuing the series by a similar article in respect to Holland.

Seeing that one of the chief characteristics of the Dutchman is to be cautious, we certainly concur with the author's remarks that there could be no better recommendation for reinforced concrete than the fact that the Dutch Government and the Dutch building owners are using reinforced concrete on a large scale.—ED.

It is a characteristic of the Dutchman that he does not venture on unsafe ground. He is a particularly cautious man. Therefore perhaps one of the best testimonials that the advocates of Reinforced Concrete can put forward is to show that it is being largely used in Holland.

There is probably no other country where concrete has been so much talked about or where its introduction has been so energetically opposed in the first instance. The prejudice against the material was intense at the outset, and its ability to resist the ravages of time was most forcibly questioned. But the opposition was eventually overcome, and the use of the material is now considerable. In fact, it has now long been adopted by the State and by the leading building owners in Holland, both as practical building material and as an exceptionally economical one.

In the first instance reinforced concrete was applied in Holland by a firm known as the Amsterdam Reinforced Concrete Works, established in 1890, and conducted under the technical management of Mr. L. A. Sanders. The firm took much trouble in collecting the technical data on reinforced concrete available at the time, and distributed it in the Dutch language, the particulars being supplemented by the results of various loading tests and experiments carried out locally.

From 1890 to 1893 the firm in question carried out a tunnel at the Wilhelmina Hospital, a fountain for the Municipality at Amsterdam, and other minor works. In 1895 they put up an external staircase, which is illustrated in *Fig.* 1, and in 1896 some of the floors and beams of the Queen's Private Record Office were constructed of reinforced concrete.

After that somewhat better headway was made, for reinforced concrete was adopted in the construction of some forts, tunnels, some locks, several bridges, and a reservoir, all civil engineering works of importance. But, nevertheless, the material cannot be said to have been popular at this period; in fact, it was still looked upon askance.

As far as the literature on the subject was concerned, there was not much to be found at this time, though there was a notable contribution to the subject in 1893, before the Dutch Institute of Engineers, by Mr. T. Nolthenius, who also presented contributions in 1894 and 1897. In 1898 a treatise by Mr. L. A. Sanders was published in the form of a series of articles, which were eventually issued in book form under the title of "Het Cement-ijzer in Theorie en Practyk." ("Reinforced Concrete in Theory and Practice.) But, although Mr. Sanders' articles ably covered the theoretical aspect of the question as viewed at that period, and although his contributions may even be said to occupy a position of some value among the international literature of the subject, it cannot be said that these writings enjoyed the attention they merited; in fact, they were not seriously considered until some few years later.

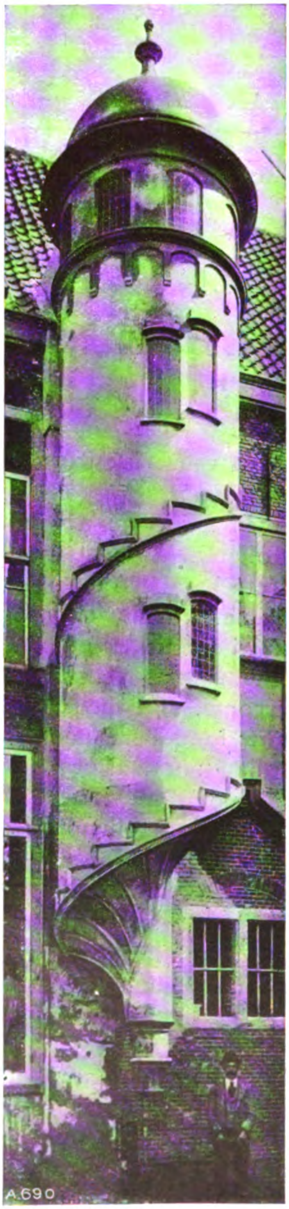


Fig. 1. Reinforced Concrete External Staircase.

In 1899, however, the Dutch Government employed reinforced concrete for floors in their large post office at Amsterdam, and this building, which has floor spans of as much as 8·5 m., may be said to have given reinforced concrete its true start in Holland.

Still, it was not until the opening of the Paris International Exhibition of 1900 that general attention was given to reinforced concrete by the technical professions of Holland. The reinforced concrete works at that exhibition were a revelation to all Dutch engineers and architects, and the large number of Dutch visitors to the exhibition in question must also have influenced what we might term the popular interest in the subject.

We find, in consequence, in the year 1900, a reflection of the interest throughout the technical and daily press of Holland, and a paper by Mr. W. Cool, delivered before the Institute of Engineers, and largely illustrated by examples, may also be said to have made a sensation.

Just about this period it will be recollected that there was a collapse of a reinforced concrete bridge at Paris, and based upon this accident

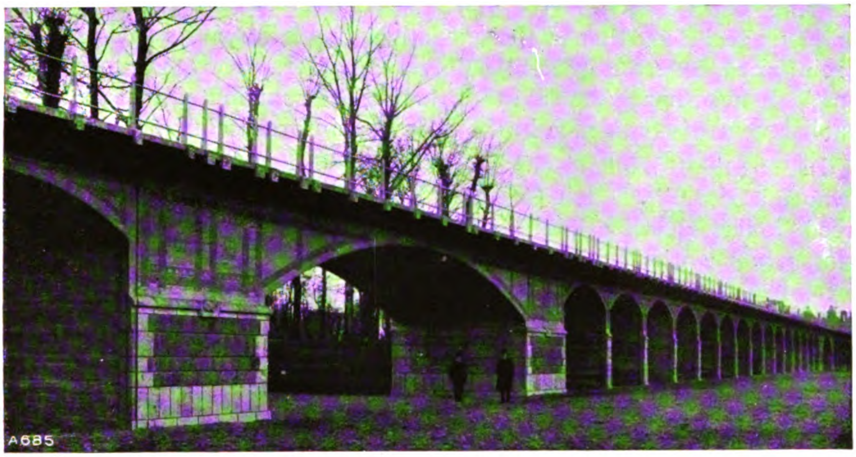


FIG. 2. REINFORCED CONCRETE RAILWAY VIADUCT AT ROTTERDAM.

such an animated controversy was commenced in the professional Press on the subject of reinforced concrete generally, that it might almost be said that this particular accident indirectly afforded the best advertisement reinforced concrete could have had in Holland. In fact, from the date of that very controversy the application of the material was greatly extended.

It was probably due to this accident, too, that three engineers of the Department of Waterways, Messrs. H. van Oordt, H. F. Beyerman, and the Honourable E. C. W. van Panhuys, were instructed by the Government to make a trip abroad for the purpose of studying the question in order to draw up a report respecting the merits of reinforced concrete as a suitable material for the construction of various classes of building. This report amounted to the

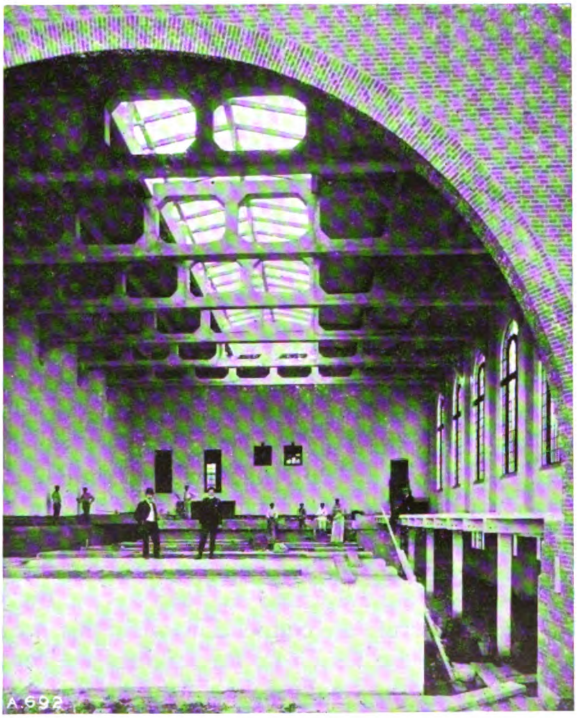


FIG. 3. AN ENGINE HOUSE WITH REINFORCED CONCRETE ROOF GIRDERS.

following conclusion:—"We have arrived at the conviction, from the studies made by us, that in the execution of public works the employment of reinforced concrete generally deserves preference over wood, stone or iron." It need hardly be said that this report contributed materially to the establishment of confidence in the uses of reinforced concrete.

In 1902 the "Hollandsche Maatschappy tot het uitvoeren van werken in gewapend beton" (Dutch Company for the execution of works in Reinforced Concrete) was established, a company which has executed a number of important works, under scientific supervision. Almost immediately after its establishment a commencement was made with the construction of a railway viaduct having a total length of about 2 km. (see *Fig.* 2). The viaduct was designed for heavy traffic, whilst the large number of streets running under it necessitated some spans of 20 to 25 m.

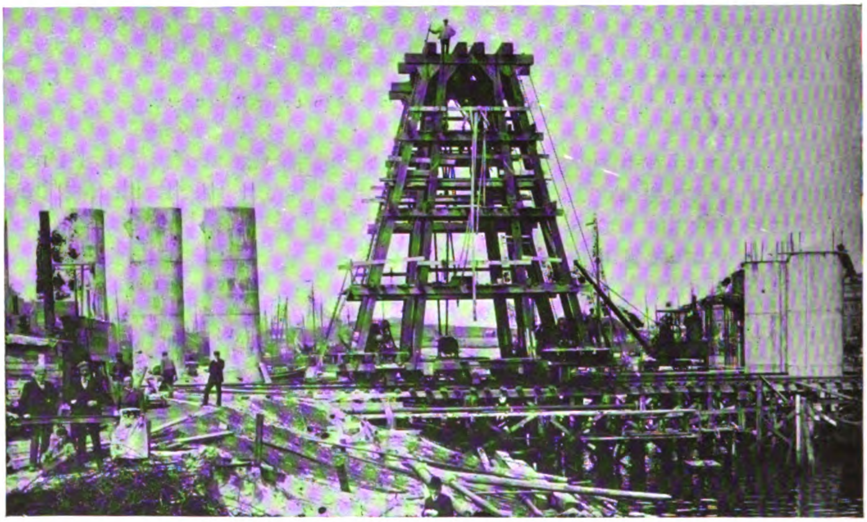


FIG. 5. REINFORCED CONCRETE QUAY-WALLS AT YMUIDEN IN COURSE OF CONSTRUCTION.

The engine house of the South Holland Electric Railway Company, which was also built during 1902-1903, was constructed by the same company. *Fig.* 3 shows the roof construction of this building, carried out according to the "Vierendeel" (quarter) system with a span of 18·20 m. Next to this engine house is situated a chimney built entirely of reinforced concrete, of a height of 63 m. The manager of this company, Mr. A. C. C. van Hemert, published in the *Ingenieur* the result of some of his experiments with reinforced concrete in connection with this work, and in a public discussion with one of the Dutch Royal Engineer officers, Captain A. P. M. Hackstroh, the question as to the reliability of reinforced concrete generally was dealt with by this eminent authority.

Foreign firms have executed but few works in Holland. At the commencement, some few examples were carried out by the representatives of Messrs. Hennebique, but these agents apparently did not enjoy popularity, and their procedure at the time, of having their plans prepared in Paris was not considered suitable for a country where such exceptional conditions prevail as in Holland. The Dutch firms, moreover, were quite competent, and patriotism is a feature in Dutch professional life.

A peculiarity in the use of reinforced concrete in Holland, as well as in certain other countries, is the fact that the appreciation of its properties is generally too much confined to a limited number of firms, who make it a speciality, and who at the same time are the financially interested parties. They, as a rule, both prepare the plans and direct the execution, and adequate control is usually wanting. In this connection the unfortunate fact must also be mentioned that side by side with the reliable specialist, the less expert—not to say ignorant—firm also nowadays offers its services as a specialist, whilst the general state of professional knowledge is as yet inadequate to easily discriminate between the true experts and the quack.

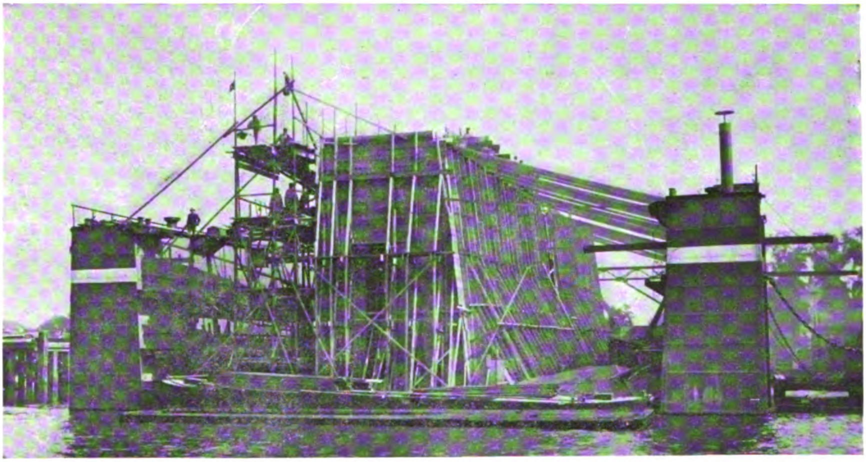


FIG. 6. CAISSONS OF REINFORCED CONCRETE FOR THE MUNICIPAL DRY DOCK AT ROTTERDAM IN COURSE OF CONSTRUCTION.

To provide against this there is no other remedy than to encourage a more general knowledge of the subject, in order that every engineer dealing with such work may be in a position to properly judge the plans for reinforced concrete construction put before him, and, if necessary, be able to personally work out his plans and details in the same manner as this is done in respect to other forms of construction. It is true that of late some improvement has been made in this direction. As a consequence some important works were executed by the Municipality of Utrecht, in accordance with the designs of their City Engineer, Mr. A. W. C. Dwars, at present

Professor at the University of Santiago de Chili (see *Fig.* 4). No specialist was employed—*i.e.*, the City Engineer dealt with the subject just as he would have with any ordinary civil engineering job.

Similarly, mainly from his own designs, some works were executed by the Hon. R. R. L. de Muralt, Engineer to the Polder "Schouwen," for the defence of the sea dykes in the province of Zeeland.

The writer of this article has also been commissioned by the Municipality of Rotterdam to prepare the plans of important reinforced concrete works, which have been undertaken by this municipality without employing specialists.

In fact, speaking generally, quite a number of engineers are now able to pass an opinion with expert knowledge in respect to a reinforced concrete project, and the number of civil engineers who can design in reinforced concrete is happily rapidly on the increase.

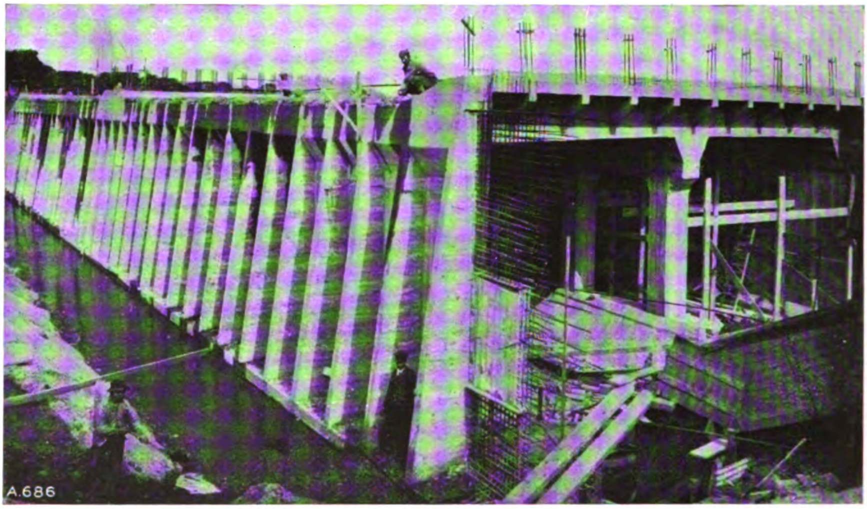


FIG. 8. REINFORCED CONCRETE SUBWAY NEAR AMSTERDAM.

A great difficulty in this connection, however, is the want of national regulations. As a rule, the German regulations are complied with, but an absolute unity does not exist in regard thereto. Fortunately, in this respect also there will soon be an improvement. On the proposal of Mr. W. Hanegraaff, member of the Royal Institute of Engineers, a committee was appointed by this body, in 1906, for the drafting of regulations for reinforced concrete in Holland. This committee has not yet completed its work, but it can already be stated that the regulations will in many respects be more liberal than the German ones, which are considered too stringent.

It is not possible to really give an idea of the large number and the great variety of reinforced concrete works which have been carried out in

Holland. It may, however, be of some importance to point out in a few words those which are specially important to the welfare of this country—*i.e.*, those concerning the harbour works, coast defence works, and canals.

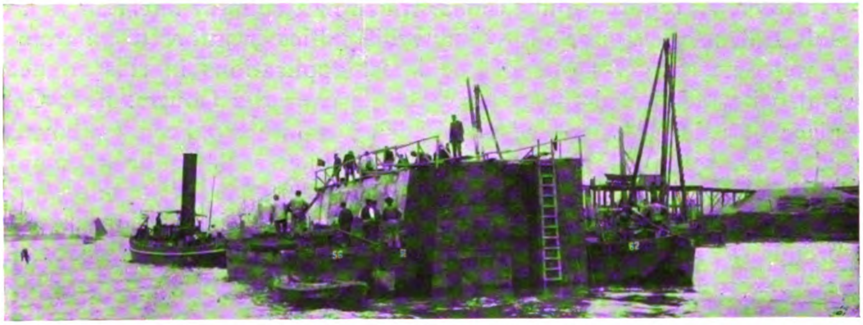


FIG. 7. FLOATING REINFORCED CONCRETE CAISSON FOR THE QUAY-WALLS AT ROTTERDAM.

As examples might be mentioned: locks in the Merwede Canal, near Utrecht; ship-building slips at Scheveningen; quay-walls, of which an illustration is here presented, for the fishing harbour at Ymuiden (*Fig.* 5). The walls are constructed of reinforced concrete cylinders, which, having been previously prepared, are subsequently driven into the sandy bottom by means of water jets. After these have been driven to a sufficient depth, a heavy superstructure, also constructed of reinforced concrete, is fixed on the top of them.

The quay walls, which at present are carried out under the supervision of the Municipality of Rotterdam, are also worthy of notice. For this purpose gigantic hollow caissons of reinforced concrete are prepared in a dry dock (*Fig.* 6). These have a length of 40 m., a height of 10 m., and a width of about 7 m. The wall thickness is from 15 to 35 cm. They are towed in a floating condition to their place (*Fig.* 7) and sunk to the bottom (which has previously been levelled) by means of admitting water into them, after which the caisson is filled with concrete and sand. When filled a single caisson does not weigh less

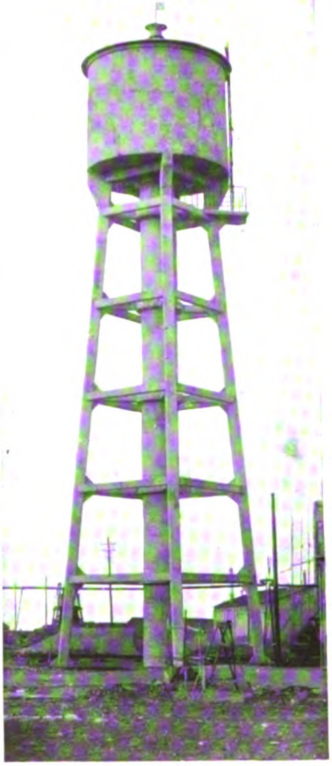


FIG. 9. REINFORCED CONCRETE WATER RESERVOIR.

than 6,000,000 kg. Upon these caissons, above the water level, are placed concrete blocks. Those who are interested in these and similar harbour works are referred to a treatise by Mr. W. Cool, C.E., which will be published on the occasion of the next shipping congress at St. Petersburg.

Further, as regards foundations, which in a country like Holland, with its soft soil, are a source of so many difficulties, reinforced concrete is a very welcome aid. As one of the latest applications in this connection may also be mentioned the railway bridge over the Gouwe, near Gouda. In place of using compressed air, which has hitherto been employed for foundations, open cylinders of reinforced concrete have been employed, which have gradually been sunk into the bottom and built upon.

In this article it has only been possible to give a few instances of reinforced concrete work, but it is hardly too much to say that the reinforced concrete works of Holland, both in regard to technical design and practical execution, bid fair to rival those of other countries.

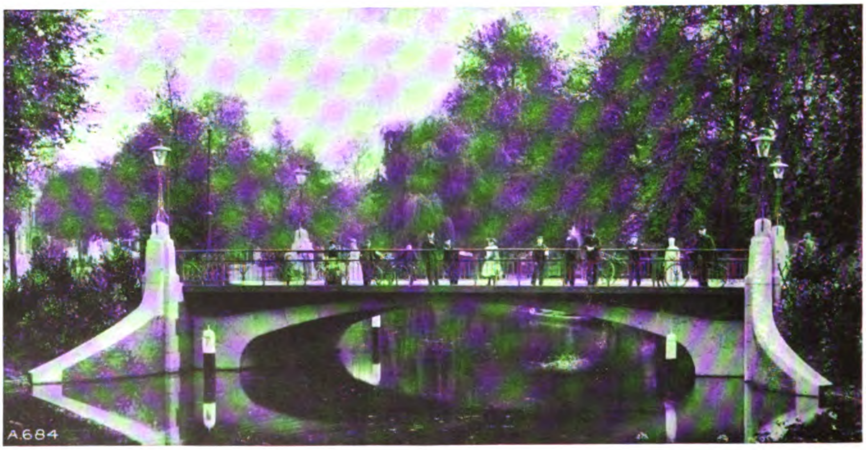


FIG. 1. REINFORCED CONCRETE BRIDGE AT UTRECHT.

Concrete Houses for the United States.

We are presenting a number of designs for domestic buildings of moderate cost, intended to be of concrete, and having an architectural treatment suitable to that material.

We reproduce these not only for our Architectural readers, but for our many readers among Engineers, Property Owners and Works Managers, who control the erection of small houses or industrial dwellings.

We would point out that in many cases where suitable aggregate is to be found on the spot, a useful building of artistic merit can frequently be put up more economically in concrete than in other material.

This fact is equally applicable at home and abroad, and thus this article may be said to bear on the building problem in the widest sense.—ED.

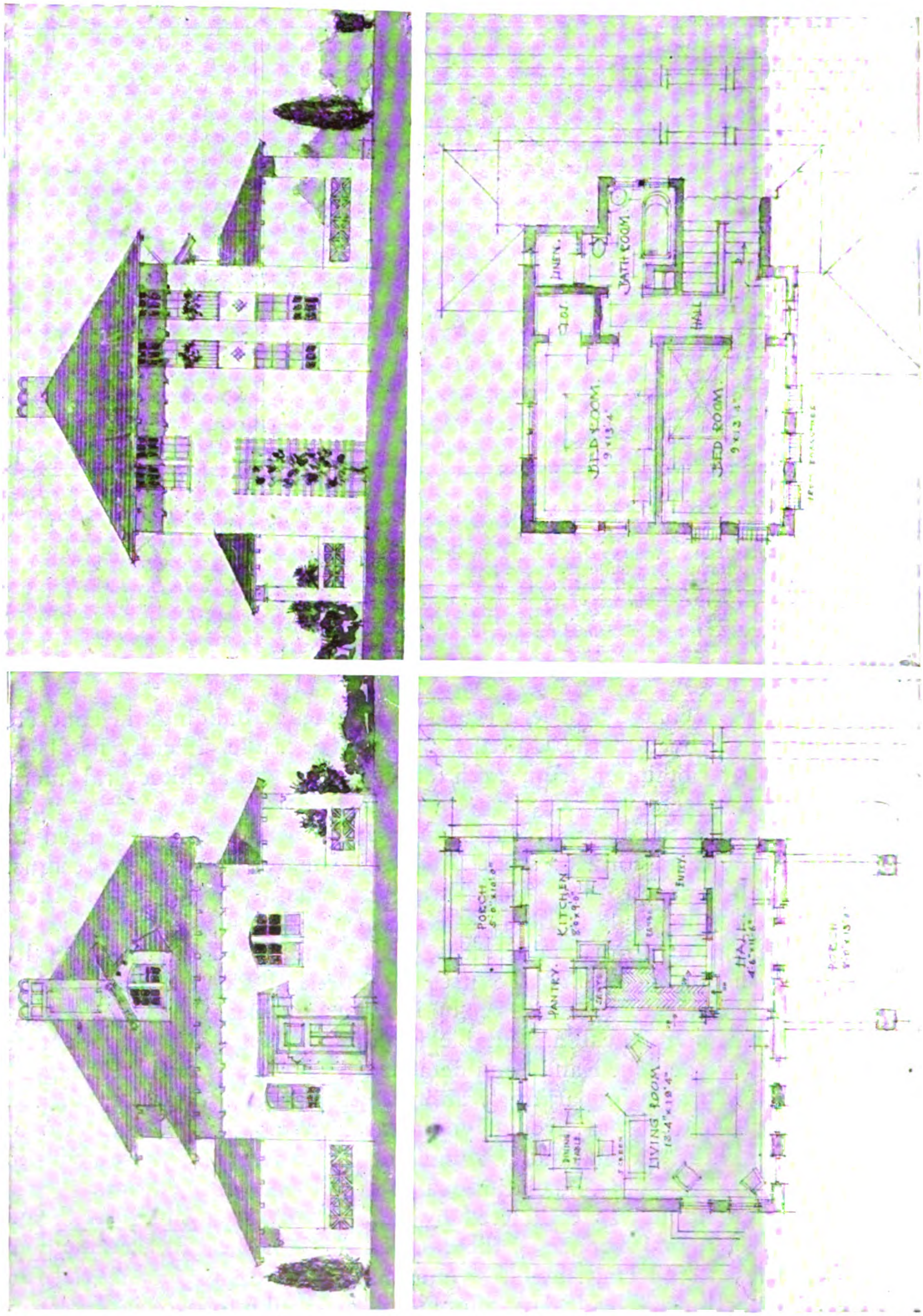
ALTHOUGH the economy of erecting small domestic buildings in concrete has long been proved in the United States, considerable difficulty has been experienced in obtaining from architects designs of architectural merit suitable for concrete work.

Architects in the United States have apparently become so used to applying brick, terra-cotta or stone dressing as a feature in their designs, even for small house property, that some effort was needed to remind them that effective results could be obtained without utilising such trimmings.

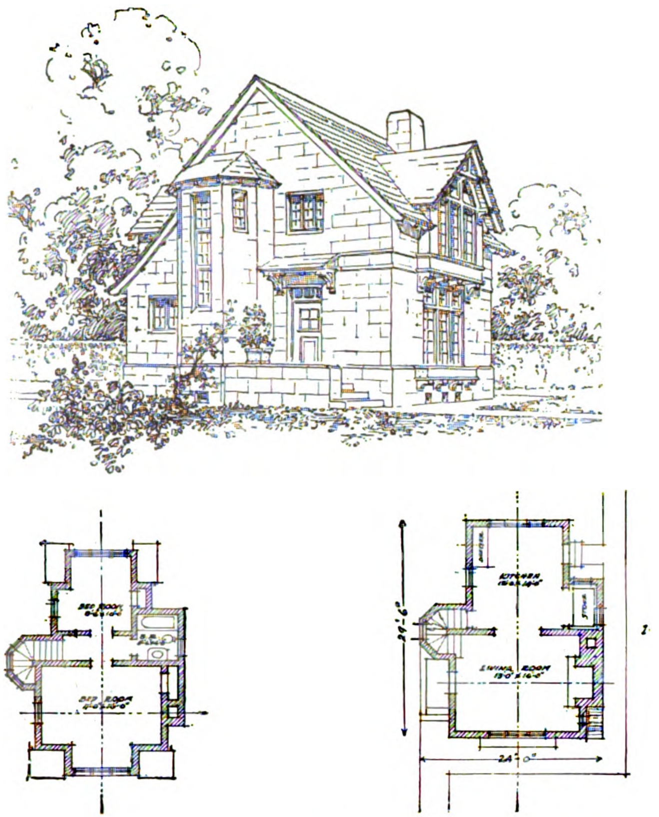
The Association of Portland Cement Manufacturers of America, naturally being desirous of increasing the uses of Portland Cement in domestic buildings, thereupon took the matter up in a very business-like way, arranging a competition for designs suitable for domestic property of moderate value, *i.e.*, for detached and semi-detached dwellings of a value ranging from £400 to £900. Comparatively liberal premiums were offered, *i.e.*, premiums sufficiently attractive for young architects, ranging from two of £40 each, two of £35 each, and two of £30 each downwards, there being in all 24 premiums, and six consolation prizes (of £8 each) in addition.

The competition was conducted by a jury of three architects, and apparently had the confidence of the competitors, for designs were sent in from all parts of the United States, and the awards appear to have given general satisfaction. The designs should be separated into two classes, *i.e.*:

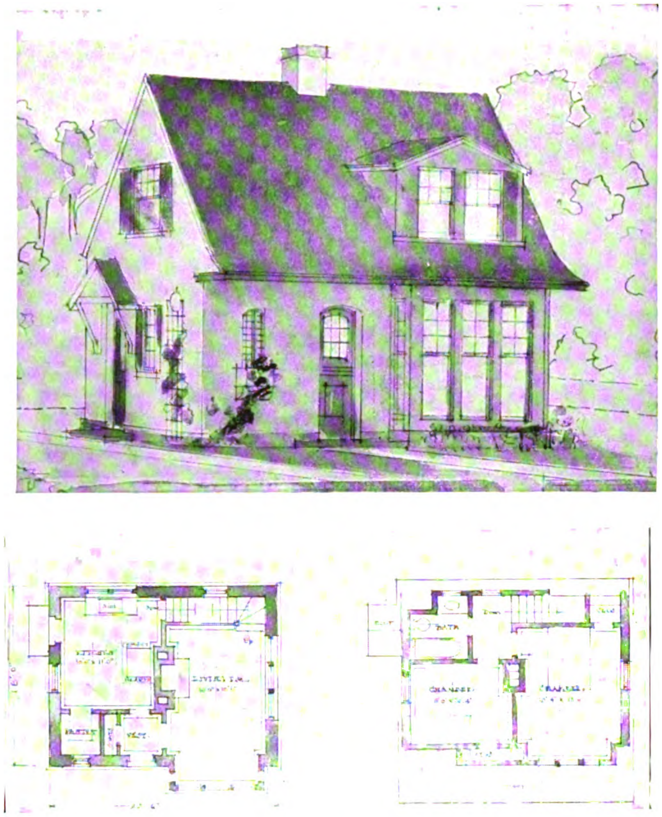
Class A.—For " single "—*i.e.*, detached dwellings.
Class B.—For " twin "—*i.e.*, semi-detached dwellings.



Class A1. First Prize—awarded to Eugene Ward, New York. (U.S.A. Cost, £391. Outer walls and porch to be of monolithic concrete construction. Cellar and porch floors to be of concrete. Outer walls 8 in. thick, cemented on outside, and rough cast finish, stained. All piers in basement, partitions on first floor and main bearing partitions on upper floors to be of hollow cement blocks, plastered. Cubic contents, 15,086 cu. ft.)



Class A1. Second Prize—awarded to David A. Clous, New York. (U.S.A. Cost, £400. All exterior walls of concrete blocks, bush-hammered face where exposed. The interior bearing wall, chimney and fire-place of concrete blocks, all lintels to be reinforced with iron ties securely fastened at both ends. Cubic contents, 10,756 cu. ft.)



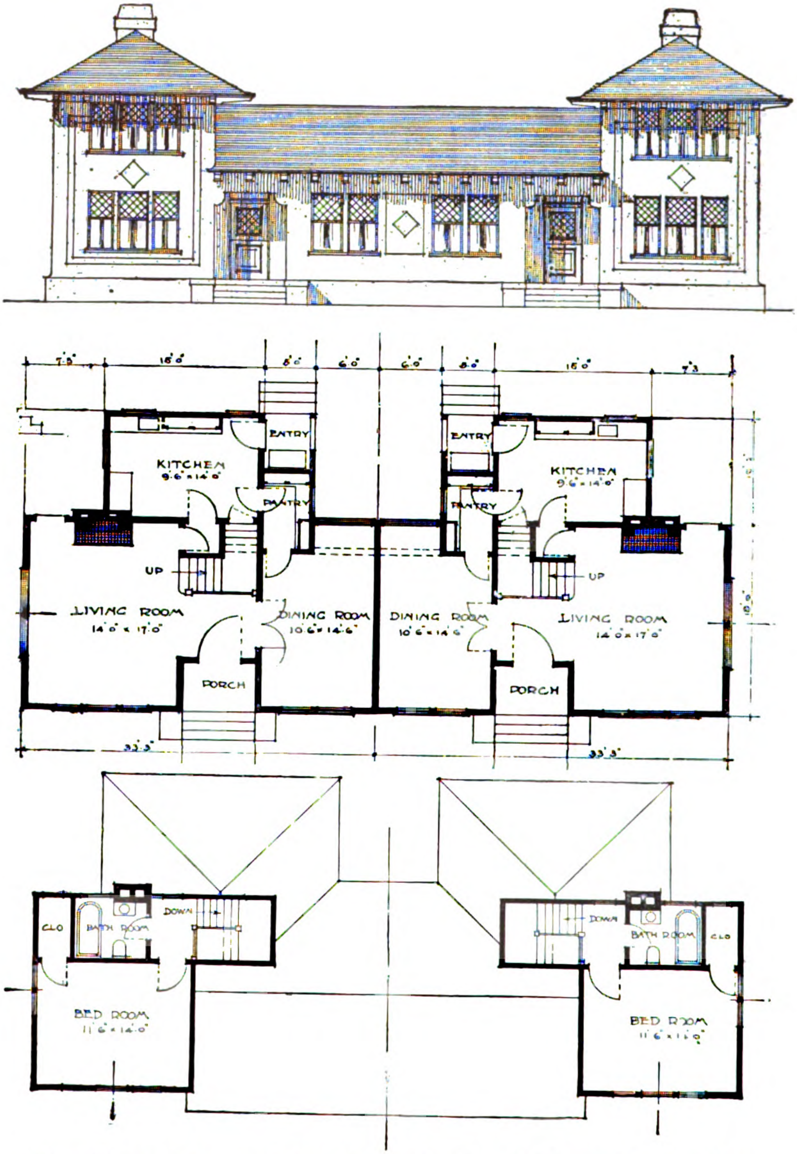
Class A1. Third Prize—awarded to I. B. Abbott and F. H. Bond, Jr., Boston. (Foundation walls of concrete. Walls of hollow concrete blocks, 1 ft. thick, plastered inside. Piers of concrete. Cellar floor, 2½ inches concrete. First storey partitions, 4-in. hollow concrete blocks. Cubic contents, 11,000 cu. ft.)

In each class, A. and B. designs were desired for dwellings providing the following accommodation:—

For sub-division 1.—Three or four rooms on 1 or 1½ floors, U.S.A. cost not to exceed £400.

For sub-division 2.—Five or six rooms on 2 floors, U.S.A. cost not to exceed £600.

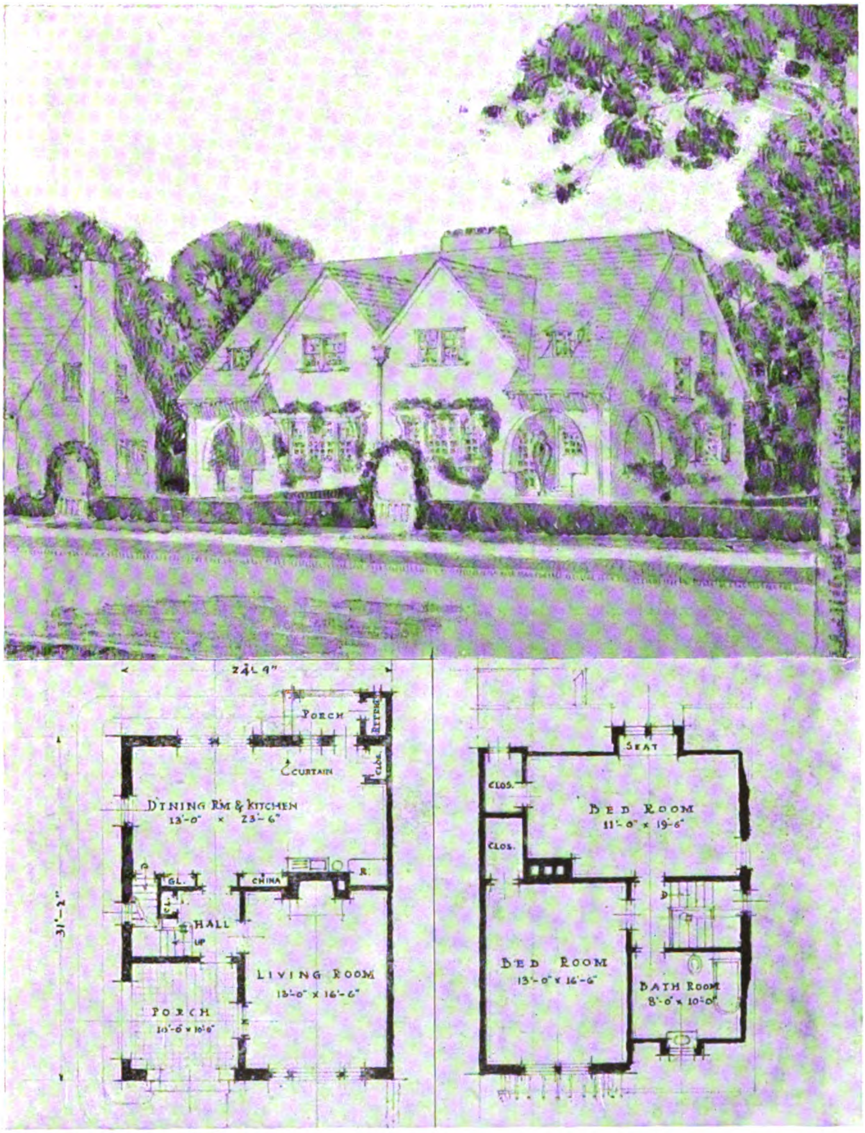
For sub-division 3.—Seven or eight rooms on 2 or 2½ floors, U.S.A. cost not to exceed £900.



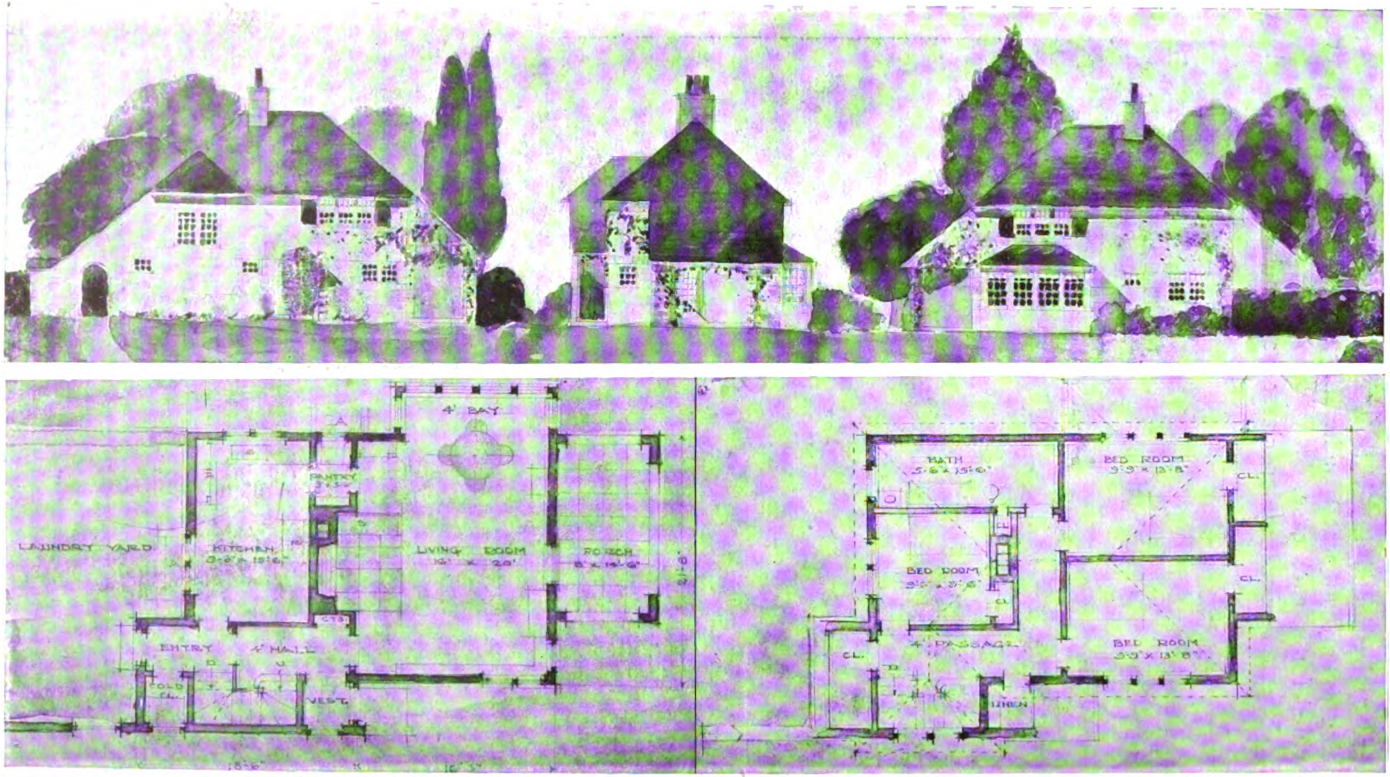
Class B1. First Prize—awarded to Andrew Lindsay, New Rochelle. (U.S.A. Cost, £792. Foundation walls of concrete, walls of hollow concrete blocks with bush-hammered face. Special blocks to form projections. Chimneys of hollow concrete blocks, and main partitions throughout of 4-in concrete blocks. Cubic contents, 33,600 cu. ft.)

The number of rooms stated does not include the bathrooms, though bathrooms were desired, and the U.S.A. cost does not provide for the general plumbing or any hot water or heating system. A cellar, however, had to be provided for in each case.

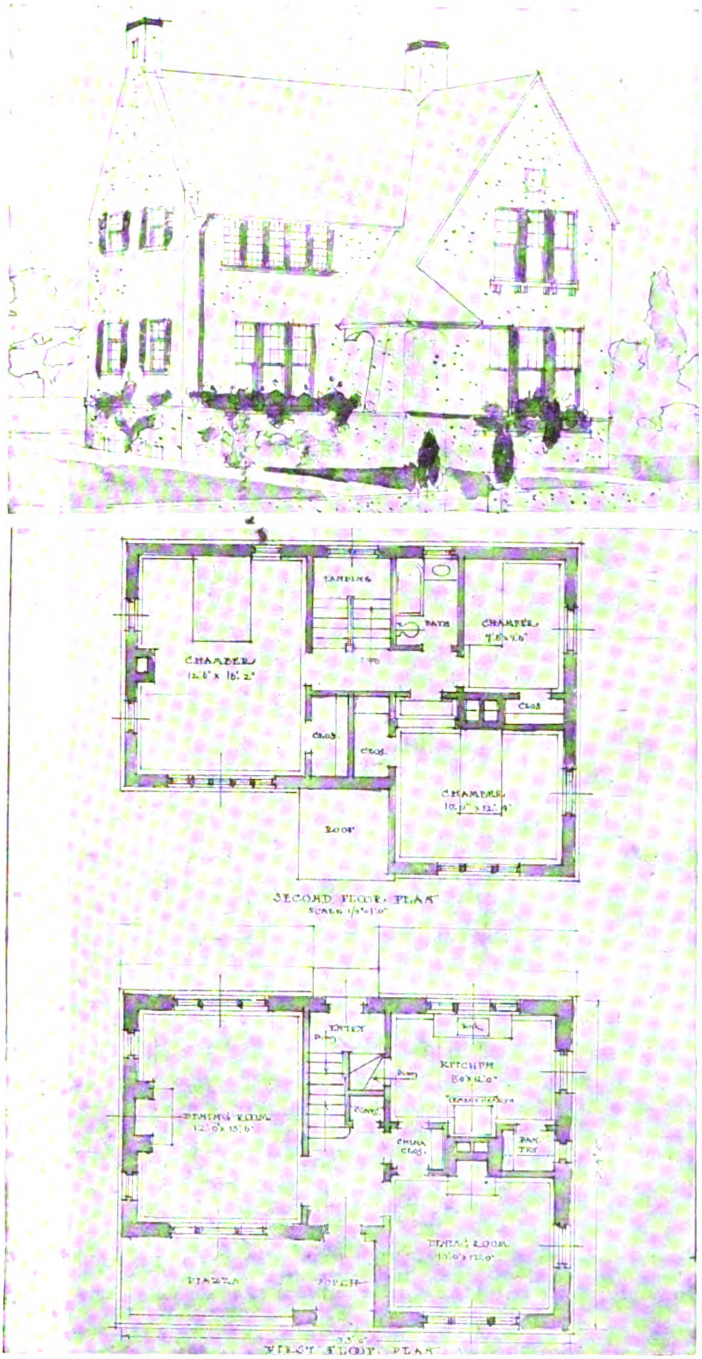
By grouping the designs under classes and sub-divisions based on



Class B1. Second Prize—awarded to George S. Idell, Philadelphia. (U.S.A. Cost, £800. The outside and party walls from footings to roof, to be built of 12-in. and 6-in. reinforced, monolithic concrete. The outside walls to be furred and plastered and the outside face bush hammered. Inside partitions throughout to be of 3-in. concrete blocks, on which plaster shall be directly applied. Cubic contents, 14,388 cu. ft.)



Class A2. First Prize—awarded to Albert G. Hopkins, Boston. (U.S.A. Cost, £569. The outside walls and vestibule of 8-in hollow concrete blocks, plain face, 12-in. monolithic foundation. Reinforced lintels, shingle roof. Cubic contents, 25,747 cu. ft.)



Class A2. Third Prize—awarded to F. H. Bond, Jr., and J. B. Abbott, Boston. (Foundations, exterior walls, etc., to be of concrete. Foundations, 1 ft 6 in. thick; first storey walls, 1 ft. thick; second storey, 8 in. thick. Cellar floor, 2½-in. concrete. First storey partitions, 4-in. hollow concrete blocks. Cubic contents, 21,400 cubic feet.)

U.S.A. cost, we arrive at the following classification, for purposes of comparison:

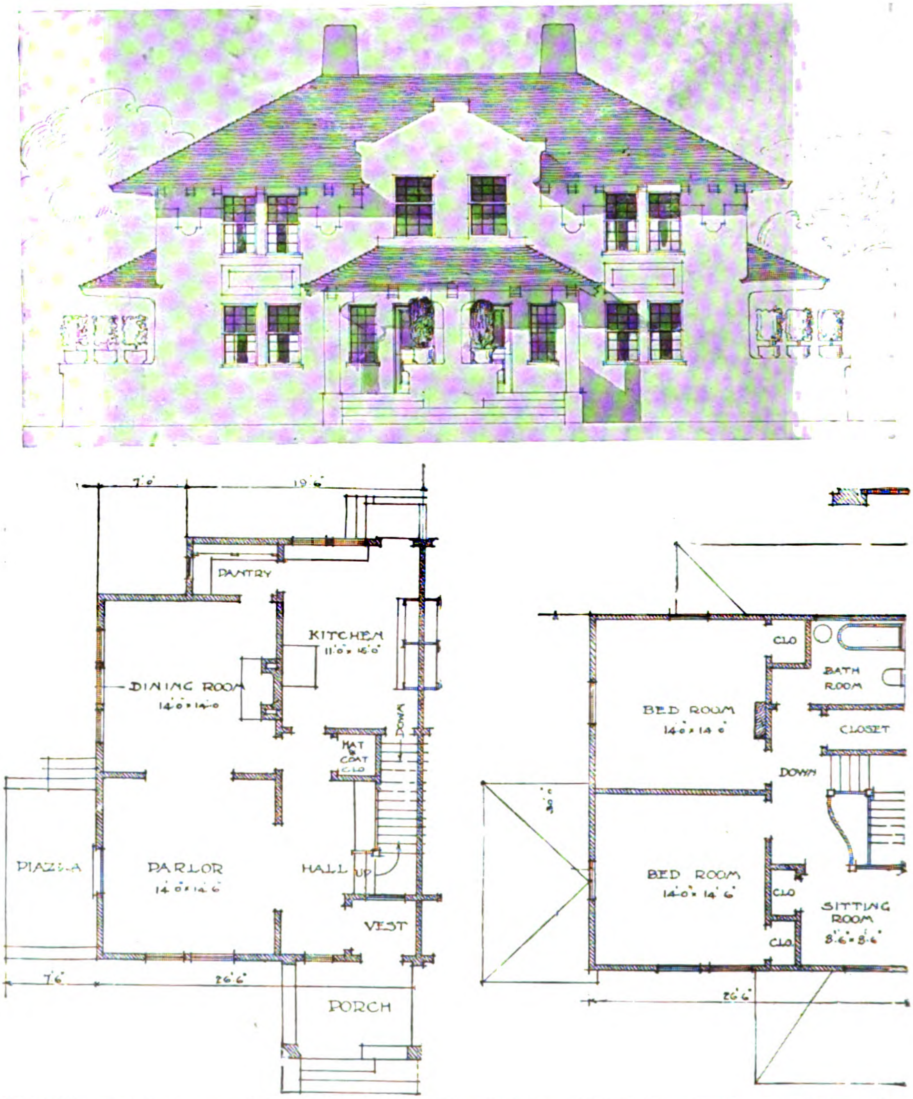
Classes A1 and B1. — Single and semi-detached dwellings, U.S.A. cost not to exceed £400 (each)

Classes A2 and B2. — Single and semi-detached dwellings, U.S.A. cost not to exceed £600 (each)

Classes A3 and B3. — Single and semi-detached dwellings, U.S.A. cost not to exceed £900 (each)

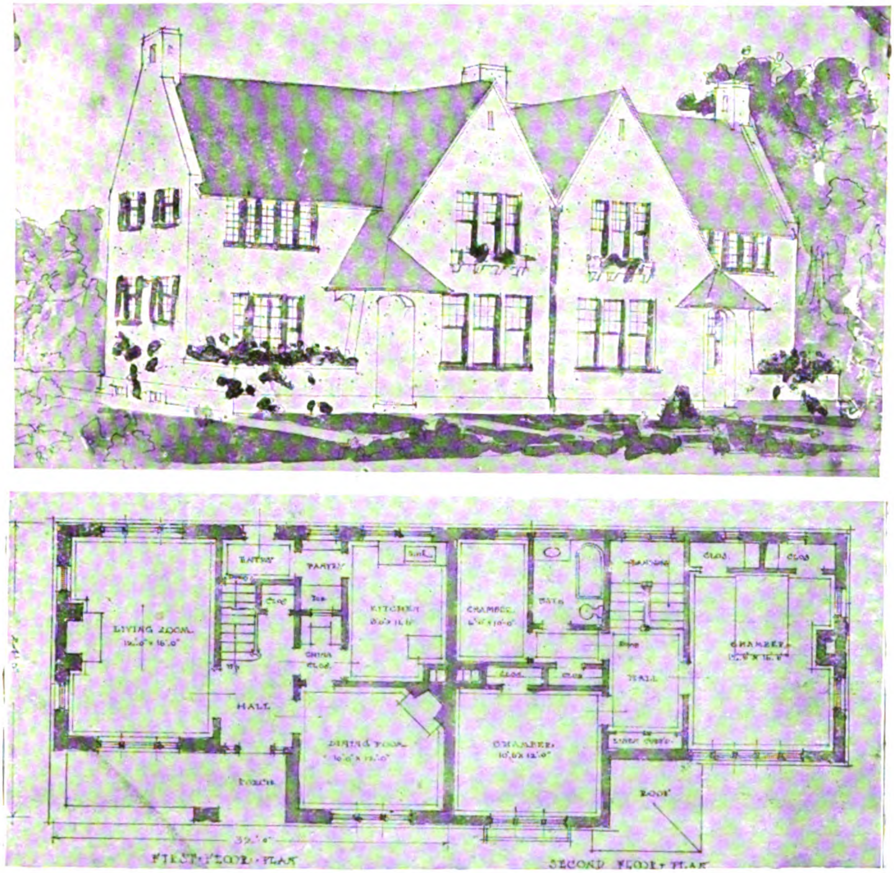
All the designs which were accorded premiums have been published in our contemporary the *Cement Age*, of New York, and it is by the courtesy of that journal that we are in this issue reproducing quite a number of the successful designs, particularly selecting those which we think would be of use to architects, contractors, estate owners, and building societies at home and in our Colonies.

We are, of course, aware that there are features of these designs by American architects that are not quite applicable at home, but they mostly relate to details of minor importance, and the designs as a whole may be taken as suitable in these islands.



Class B2. First Prize—awarded to Andrew Lindsay, New Rochelle. (U.S.A. Cost, £1,179. Foundation walls up to the level of first floor beams to be of monolithic concrete construction, above that of hollow concrete blocks with bush-hammered face. Chimneys of hollow concrete blocks, main partitions of 4 in. ditto. Cubic contents 61,000 cu. ft.)

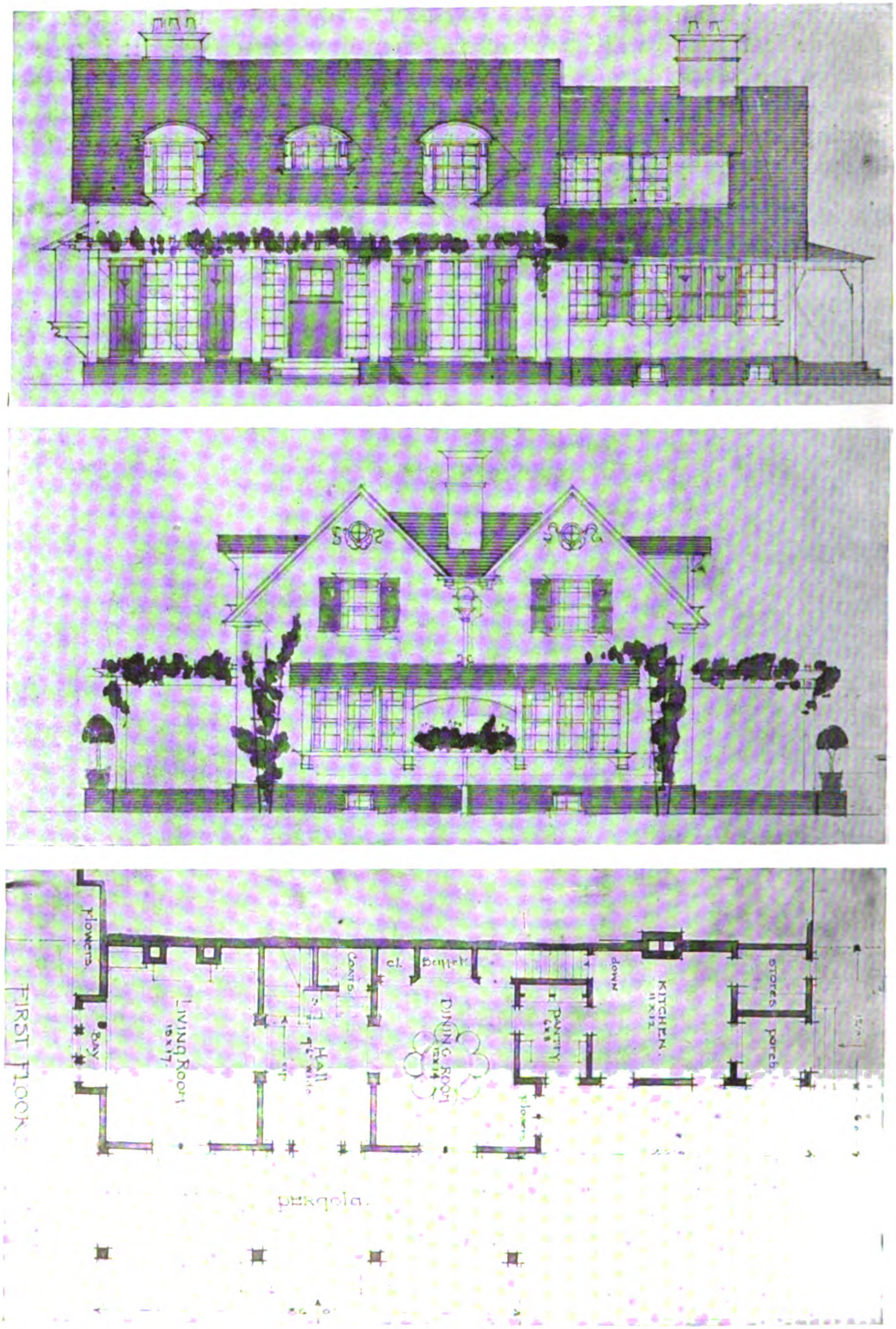
The particular reason why we reproduce the drawings from this competition is to remind our readers that small buildings can be put up that have architectural merit, and yet need not necessarily have the brick, terra-cotta or stone features to which we are so generally accustomed. It is true that some of the competitors have introduced such features in the form of special concrete blocks or artificial stone, but we do not consider the designs showing such features to quite accord with what was required, or to be in the spirit generally adopted in this competition.



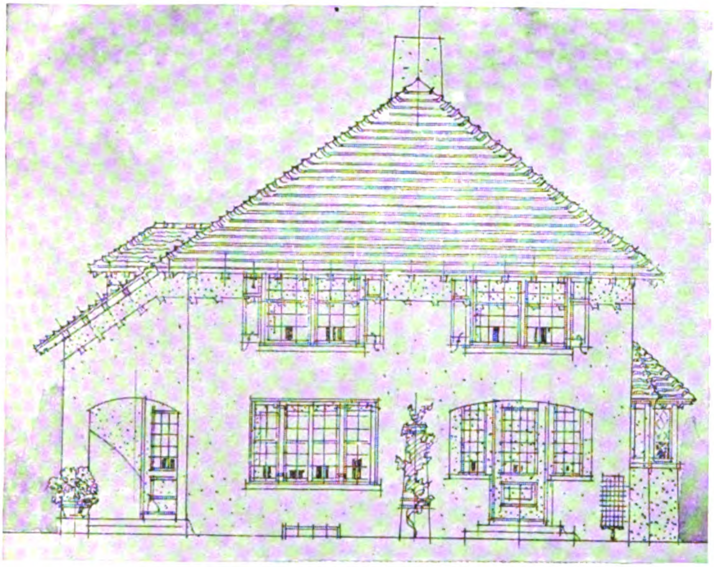
Class B2. Second Prize—awarded to L. B. Abbott & F. H. Bond, Jr., Boston. (Foundations, walls, piers, porch, floors and rails, steps, areas, window mullions, etc., of concrete, laid up monolith in wooden forms. The material from the forms to be used for roof boarding, etc. Foundations to be 1 ft. 6 in. thick, first storey walls, 1 ft. thick; second storey walls, 8 in. thick. The concrete walls to be tinted. Cellar under whole house, floors of which are 2½ in. concrete. First storey partitions, 4-in. hollow concrete blocks, plastered).

We are naturally aware that, as far as planning is concerned, these designs are for the most part as equally suitable for brickwork as they are for concrete, but the majority, as far as external treatment is concerned, are intended for *bona fide* concrete work, and as such they should form quite a valuable collection for reference purposes.

As to the values, these buildings were designed for American purposes



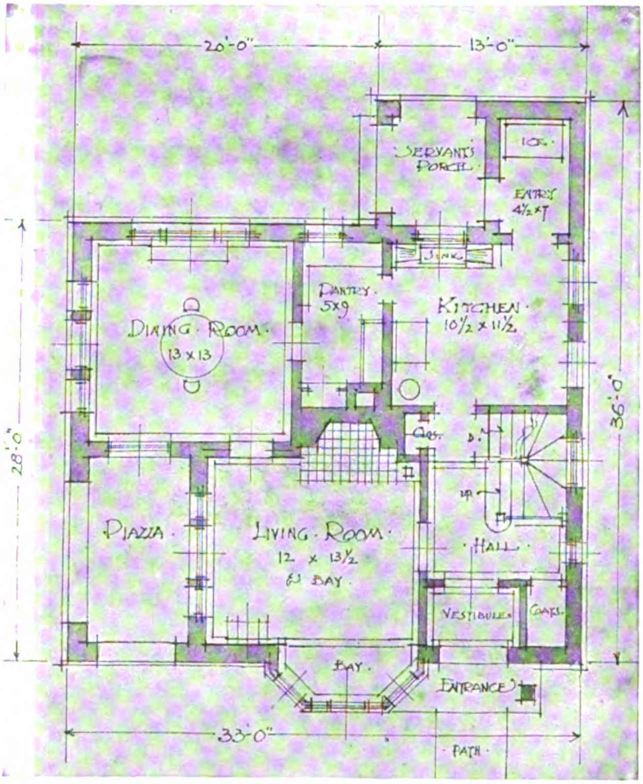
Class B2. Third prize—awarded to Lindley Johnson, Philadelphia. (U.S.A. Cost, £548. Reinforced concrete for all exterior walls above first floor level. Cellar walls to be of stone concrete or brick. Interior partitions of 3-in. concrete blocks. Approximate cost per cu. ft., 6d. Cubic contents, 22,855 cu. ft.)



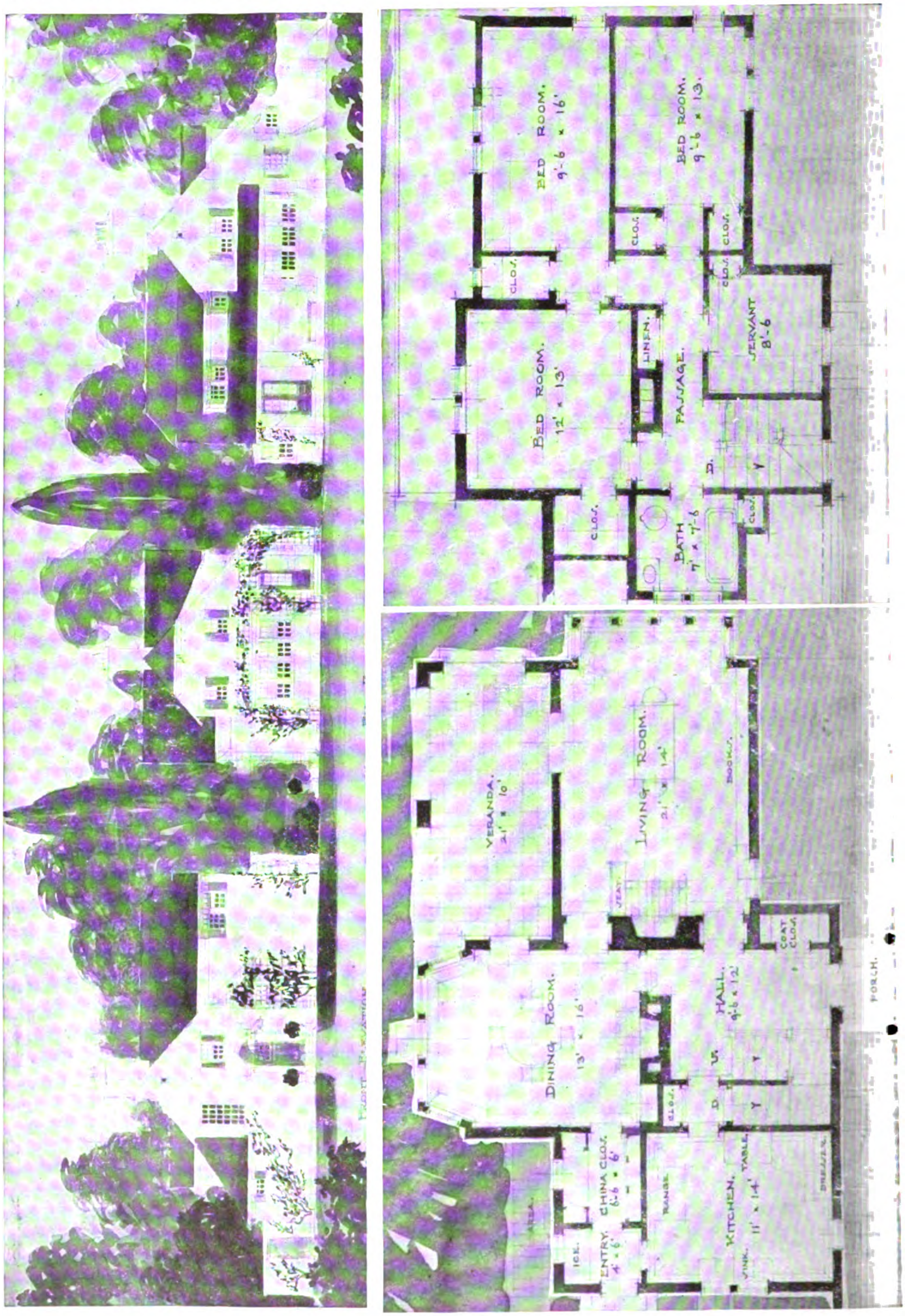
and to meet American cost. We give the American values, but at the same time we give the cubic contents of each structure, so that the English or Colonial architect, as the case may be, will be able to find, by their cubic contents, the figure he considers to be locally correct, and thus what would be the local cost.

As to the utility of concrete for similar buildings to those illustrated there can be no doubt, and the question of the application of concrete for such buildings will probably soon be reduced to simply a question of relative cost.

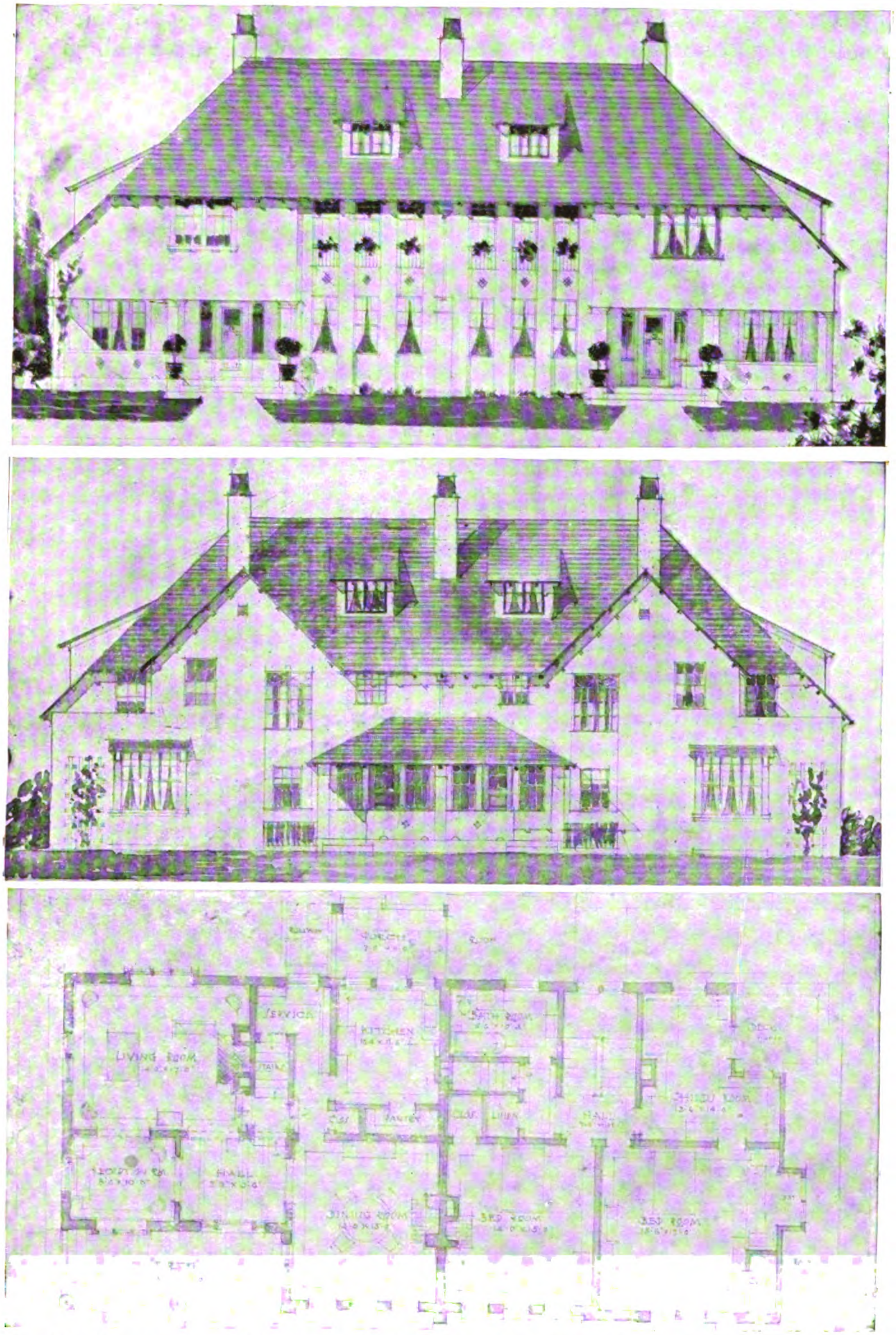
As far as relative cost is concerned, it must vary in different districts, according to the facilities for obtaining brick as against the facilities for obtaining the necessary aggregate and Portland Cement. In many cases it will thus be the price of carriage which will settle



Class A3. First Prize—awarded to W. Cornell Appleton, Newton Center, Mass. (U.S.A. Cost, £871. Monolithic concrete walls. 4×8×16-in. hollow block partitions in first story. Concrete block chimneys. Cubic contents, 37,052 cu. ft.)

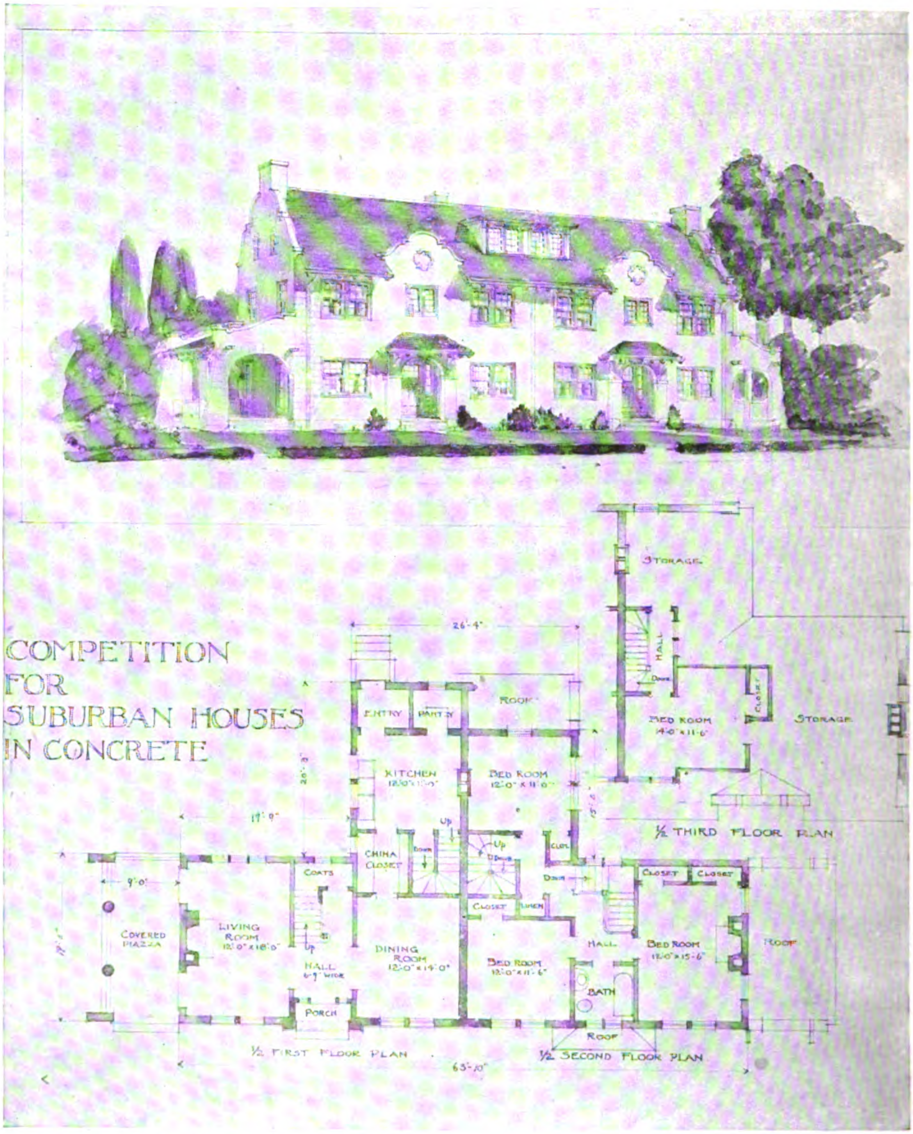


Class A3. Second Prize—awarded to Albert S. Hopkins, Boston. (U.S.A. Cost, £768. Foundations walls of monolithic concrete. Walls of plain faced concrete blocks, 8 in. thick, 12 in. high, 12, 24 and 30 in. long. Verandah piers, 12-in. blocks. Reinforced lintels over windows. Cubic contents, 31,500 cu. ft.)



Class B3. First Prize—awarded to Eugene Ward, Jr., New York. (U.S.A. Cost, £1,797. Outer walls, etc., to be of monolithic concrete, cellar and porch floors of concrete. Outer walls, 8 in. thick. All piers in basement, partitions on first floor, and main bearing partitions on upper floors to be of hollow cement blocks plastered. Cubic contents, 35,000 cu. ft.)

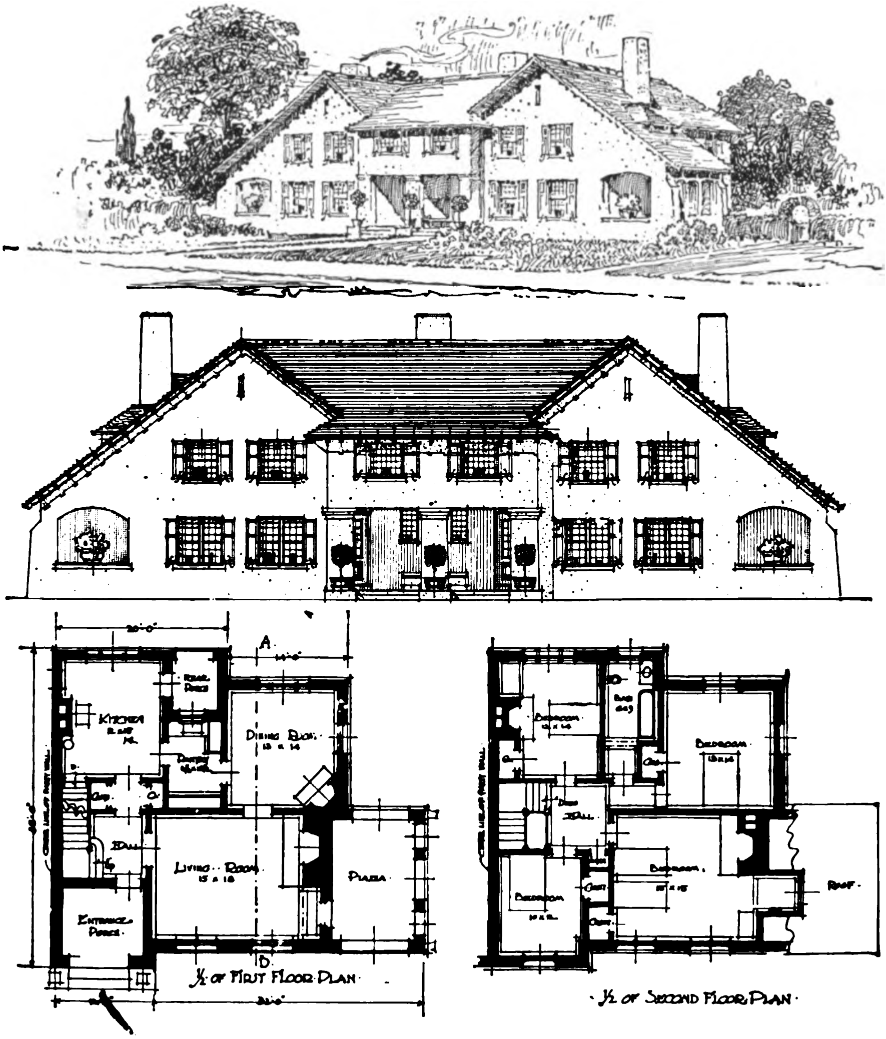
the whole matter, for should the aggregate actually be obtainable on the building site, or within close proximity to the scene of the building opera-



Class B3. Second Prize—awarded to Benjamin Proctor, Boston. (U.S.A. Cost, £1,800. Exterior walls and foundations of hollow concrete blocks, also first story partitions. Columns, balustrades copings, and copings on gables, and chimneys above roof to be of concrete. Cubic contents, 62,567 cu. ft.)

tions, it may be generally assumed that concrete will have the advantage in cost, even where bricks are obtainable close at hand.

We trust the illustrations presented will be found useful, and assist in overcoming a certain prejudice that a concrete house must necessarily be an ugly one.



Class B3. Third Prize—awarded to W. Cornell Appleton, Newton Center, Mass. (U.S.A. Cost, £896. Walls monolithic. Party wall and first storey partitions of hollow concrete blocks. Chimneys of hollow concrete blocks with a skim coat on exterior. Cubic contents, 42,400 cu. ft.)

THE SETTING OF PORTLAND CEMENT.

ARTICLE IX.

A Short Summary of the Questions which have been debated in our previous issues.

By BERTRAM BLOUNT, F.I.C.

We have published from time to time valuable articles on The Setting of Portland Cement, by various leading authorities, both home and foreign, and the series issued should be of considerable value for reference purposes to all engaged in the manufacture and use of cement.

In this issue we present an article prepared at our request by Mr. Bertram Blount, F.I.C., whose connection with Portland Cement is so well known, and his summary of the present state of knowledge on the subject should make many ponder who have definite views, whilst it should stimulate to further effort all those engaged in research work.—ED.

THE Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING has asked me to summarise the present state of our knowledge on the question of the setting of Portland cement. If I were to comply literally with this request, this article would consist of a list of empirical observations pleasingly isolated, free from any correlation likely to impair their individual value. But although knowledge, in the proper sense of co-ordinated facts, is abundantly lacking, there is ample speculation to afford a nexus useful as an aid to thought, if it is recognised as plastic and temporary. The existence of such a mode of linkage justifies presentation of something more than a catalogue.

Some years ago it was generally believed that all requisite knowledge of the setting of Portland cement had been acquired. It was then supposed that the setting depended on the hydration of a calcium aluminate, to which the formula $3\ CaO\ Al_2O_3$ was usually assigned, and that the rapidity of setting depended on the proportion of this aluminate—the higher the proportion the quicker the setting; that a cement setting quickly when fresh would become slower setting as it was matured on account of the hydration of a part of this aluminate. It was accepted that the addition of gypsum inhibited the hydration of the aluminate, and that the inhibitory effect disappeared on keeping the cement, probably because of the carbonation of uncombined lime which was jointly necessary with the gypsum to restrain the hydration of the aluminate. There were, of course, minor questions which required and obtained some sort of explanation, but with these axioms as a guide the expert found his path broad and plain.

At the present time the situation is by no means so simple. The belief that the essential constituent concerned in the setting of cement is an aluminate remains, but the identity of the aluminate is doubtful. The mechanism by which the doubtful aluminate sets is supposed to be the hydration of this substance, its dissolution to a supersaturated solution, the deposition of the surplus, the re-formation of a supersaturated solution, and so *da capo*. But in addition to the doubt as the composition of the aluminate, it appears that there is no direct evidence of the aluminate forming a supersaturated solution. Further, it is not easy to understand why a small amount of water, *e.g.* 1 per cent., absorbed by the cement during storage, capable of hydrating only a small proportion of the aluminate, can profoundly modify the time of setting, as it certainly does. Also it is now known that there are many cements of normal ultimate composition which become quicker setting on aeration, a fact necessitating the introduction of some other explanation than the mere hydration of a part of the aluminate. Again, it is recognised that cements are not uncommon the setting time of which is but little influenced by gypsum. Other cements there are which have a false or flash setting time, and others again which, while setting in a reasonable time in the testing room, are uncontrollably fast or inconveniently slow when put into actual use. In face of these facts, anomalies as they would once have been called, that easy dogmatism which once satisfied the enquirer is out of date, and must be replaced by a more reasoned explanation of the causes of the setting of cement based on wider experimental knowledge.

There are two aspects of the setting time question which need to be separately considered. The first is the enquiry: What are the chemical and physical causes and operations which govern the process of setting? The question is of high scientific interest and much complexity, and, as shown above, cannot yet be answered; accurate data are almost completely lacking. Even the mechanism of the setting of plaster of Paris, a simple substance which has been studied in detail for nearly a hundred and fifty years, is still not precisely known. The complex materials constituting Portland cement have as yet scarcely been isolated, and their behaviour as individuals is almost entirely unknown. Until this detailed knowledge has been gained, generalisation must be confined to some such simple hypothesis as that given above, and at present commonly accepted, it being well understood that it is no more than an hypothesis; in consequence of the very limited value of a generalisation so imperfect, each case of "anomalous" setting must be studied as an individual and on its merits.

The second aspect of the setting time question is wholly practical. It is: How to ensure that a cement procured for a given piece of work shall set in a suitable manner?

When it is considered that in ordinary construction the cement may be mixed in proportions varying from 1 : 1 to 1 : 12, and may be handled in a time varying from a few minutes to an hour, and may be exposed to a load in a few days, it will be seen that the conditions are onerous.* A cement certain to meet these conditions must remain inert for at least one hour; after that time the quicker it sets the better. It remains to consider whether such a cement can be regularly made, and whether its quality can be properly tested before it is used.

Take the second and easier part of the question first. Clearly the ordinary methods of the testing room are insufficient. There pats of neat cement, most carefully gauged, kept at a known and uniform temperature, and protected from evaporation, are used to ascertain the setting time. In practice a mass of stone and sand mixed wholesale with the cement, mixture being aided by a liberal supply of water, is dumped into place under any sort of weather conditions which may prevail. The gap between the two procedures is too wide. A useful intermediate step would be to make, as a matter of routine obligatory as is ordinary testing, blocks of concrete from the aggregate which it is intended to use, and mixed, not with the metriculous precision of a skilled gauger, but with just that ordinary amount of skill and care which can be expected from a good labourer. Such a mode of testing, rough though it is, would be a useful guide to the behaviour of the material in the work.

---

* The special case of cement required to set under water, or so quickly as to bear almost immediate immersion, is omitted for simplicity in argument.

Next, as to the task of the manufacturer, which is to produce a cement which shall have a considerable period of quiescence after it has been mixed with water, and shall then set rapidly. Until the causes of setting are accurately known, the maker in seeking to produce such a cement must proceed empirically. And in attempting his task he must remember what has been brought about by the conversion of cement manufacture from the fixed kiln process to the present process with rotatory kilns. In the old process there was a mixture of well-burnt clinker, relatively high in lime, with under-burnt material and material containing the ash of the fuel; the composition of these three substances differs substantially. In the present process the whole of the product is of the same ultimate composition. It is quite conceivable that the under-burnt material and the material containing the ash of the fuel, and relatively poor in lime, are the chief agents in determining the setting time of the cement and in influencing alteration of the setting time. As this adventitious material does not occur in rotatory clinker, the setting of rotatory cement depends upon the properties of those chemical compounds alone which constitute fully burnt clinker. In short, by the introduction of the rotatory kiln, Portland cement, almost as uniform as it is when made in the laboratory, has become an article of commerce. Differing as it does from the mixed product from fixed kilns, its properties naturally differ and must be studied apart. It follows that methods of controlling setting time—*e.g.*, by adding water, gypsum, or by storage, whose effects are fairly understood—though their rationale may not be—when they are applied to fixed kiln clinker, will give different results with rotatory clinker of the same *mean* composition. Experience shows that this expectation is warranted.

As long as our present state of ignorance as to the real mechanism of setting continues, all progress must be empirical. Various devices, including probably the addition to clinker, which sets badly but hardens well, of some preparation which is of value merely for setting, are being and will be tried, and it is not unlikely that some of these will prove effective. But until the chemistry of Portland cement is understood to a point when it is possible to assign to each constituent its true *rôle*, not merely alone, but in the presence of its fellows, unforeseen difficulties, paradoxical phenomena will be encountered, and explanations will be guesses or glosses.

The Application of Reinforced Concrete for the Construction of Fire-Resisting Buildings

By JAMES SHEPPARD, A.Inst.E.E.,

Surveyor to the North British and Mercantile Insurance Co.

Supplementing the Author's remarks in "Concrete" for March, 1907, and having special reference to a paper on the subject by F. A. Macdonald published in "Concrete" for July, 1907

As indicated in our July issue, Mr. Macdonald's paper, read before the Insurance Institute of Edinburgh, was a most valuable contribution on the subject of the fire resistance of reinforced concrete, and particularly useful as coming from one associated with a reinforced concrete system (Hennebique System).

We now publish a commentary on the paper by Mr. James Sheppard, A.Inst.E.E. (Surveyor to the North British and Mercantile Insurance Company), in continuation of his valuable article of March last.

Mr. Sheppard's argument is mainly one for reasonable discrimination between the requirements of fire-resistance in ordinary buildings, as compared with those of the warehouse and factory class.

We would warn those concerned particularly against insufficient covering of the metal rods in buildings stocked with inflammable merchandise. The value of a sufficient covering is still all too generally forgotten.—ED.

IT is encouraging to meet with responsible engineers having financial interests in important systems of reinforced concrete construction willing to admit that special provisions are necessary to secure satisfactory resistance to fire in buildings erected on their own or other similar systems.

The provisional report of the committee constituted by the Royal Institute of British Architects, on reinforced concrete, contains valuable suggestions on this important subject, affording still further encouragement.

It would therefore appear that efforts made by the British Fire Prevention Committee to interest architects, engineers, building owners and the public in the fire-resisting character of various materials and methods of construction, have not been in vain

It may be expected that for the future, buildings although of sufficient strength to carry (under normal conditions) the loads provided for, will not continue to be proclaimed fire resisting on the grounds simply that only incombustible materials have been used in their construction.

Mr. Macdonald will doubtless, on further consideration, also fall into line with the conclusions of other leading authorities with regard to the thickness of insulating materials necessary to afford adequate protection both for the concrete and the steel, based on reliable data obtained at *serious* fires and official tests on full-sized structural units, conducted by the above-mentioned Committee.

NATURAL LAWS.

Natural laws, applicable to the different materials used in reinforced concrete, need to be considered and adequately provided for when constructing buildings intended to be fire resisting.

Much has been made of the fact that the co-efficient of expansion and contraction of steel and concrete under changes of temperature are practically the same, but from the relative position of these materials when combined in reinforced concrete, as well as from their wide difference of heat conductivity, they do not reach equal temperatures at the same time when subject to fire from the burning of goods stored in buildings constructed with the materials named.

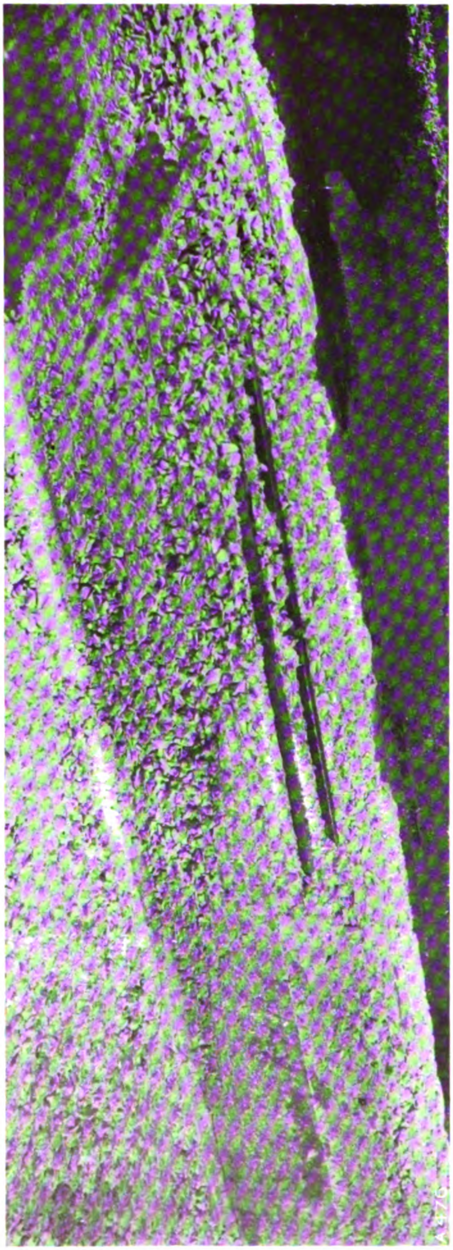


Fig. 1. Characteristic Spalling of Concrete Covering to Bars in Reinforced Concrete where the Bars are Improperly Protected.

In a laboratory test, referred to in a former paper,* concrete in one of the beams under test expanded longitudinally in the length of 6 ft., $\frac{5}{8}$ of an in. more than a $\frac{3}{4}$ in. dia. steel rod embedded therein, the difference in expansion being obviously influenced by the location of the steel rod. Other instances could be presented.

Steel, according to the best authorities, commences to lose its power of resistance to stress at a temperature of about 400° Fahr., and at 770° Fahr. loses 50 per cent. of such resistance, becoming plastic at less than 1000° Fahr.

Concrete depends for its permanence and strength on the existence of water-carrying crystals, formed as the cement sets and hardens, binding the aggregates into one mass. The water necessary for the maintenance of these crystals, and consequently for the strength of the concrete, is gradually decomposed on being subjected to a temperature of 600° Fahr.

As a result of these inevitable laws, concrete, even when made with good cement and aggregates of suitable materials and size, gradually deteriorates when subjected to a temperature of 600° Fahr., and steel also at a temperature of about 400° Fahr.

NECESSARY PROTECTION TO STEEL RODS.

It is, therefore, of the utmost importance to provide *ample* protection so that the temperatures named may not reach any part of the concrete or steel needed for structural stability under full loads, which loads, in the event of fire amongst the goods stored, would be materially increased by water used to extinguish or prevent the spread of fire.

---

* "The Application of Reinforced Concrete for the Construction of Fire-resisting Buildings," Concrete & Constructional Engineering, Vol. II., No. 1, March, 1907.

What as a rule happens where rods are insufficiently protected may be seen from *Fig.* 1, which is a characteristic instance of the usual effect of high temperature on beams having protection under 2 in.

The corrosion of steel in reinforced concrete appears to result from voids occurring in the concrete more than from the nature of the aggregate used. To secure full resistance to fire it is also important that the concrete be solid throughout.

In office, domestic, or other buildings, which would not be subject to a continued high temperature on the burning of their contents, a moderate addition to the thickness of concrete needed for structural purposes may be sufficient, especially if porous aggregates, which have been found to delay the decomposition of water, are used for the outer portions of the concrete.

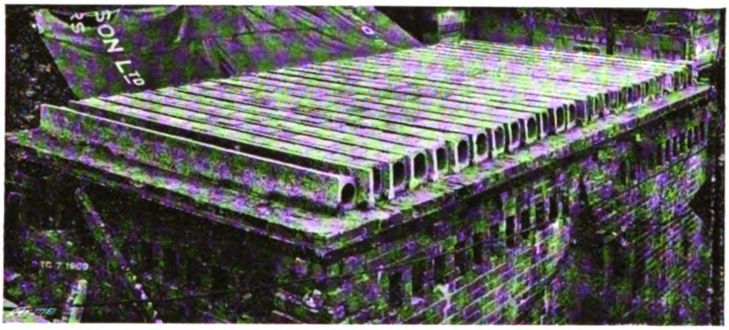


FIG. 2. FLOOR ON THE HERBST SYSTEM (*showing the construction*).

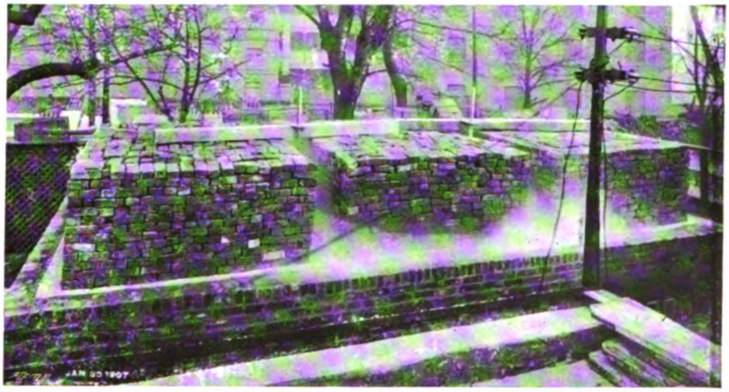


FIG. 3. FLOOR ON THE HERBST SYSTEM (*view during test*).

In buildings of this class 1½ in. to 2 in. of concrete for beams, and 1 in. for small floor slabs in front of all metal work, as stated in the Report of the Royal Institute of British Architects, may be sufficient, but even in such buildings further protection for heavily-loaded girders and columns and floor slabs of large area is desirable.

The examples referred to by Mr. Macdonald[†] were buildings of this character, or were cases in which the fire was not allowed to attain great heat.

[†] The examples referred to by Mr. Macdonald were not quoted in this journal, as the information he had drawn upon was apparently not of the independent character at our disposal. The examples were, however, published in a contemporary.—ED.

The Baltimore case, although a small office building, suffered severely on the upper floors, and if this building had been fully loaded with combustible goods, the burning of which would have subjected the building to heat for a longer time, it must have collapsed.

The failure of reinforced concrete beams and of girders embedded in concrete in the San Francisco conflagration was very general, chiefly in consequence of insufficient protection. The Newcastle example was one in which the temperatures attained were only low, while the Frankfort instance does not, in the view of the local authorities, rank as a serious fire, but as an explosion—*i.e.*, an instance where the excellent resistance of reinforced concrete to shock alone could be properly quoted.

In extensive buildings used for the storage of large quantities of combustible goods full protection is needed, both for the concrete and the steel, if reliable resistance to fire is required.

The burning of the contents of such buildings produces the "very high temperatures and most severe conditions" contemplated in the report of the Royal Institute of British Architects, to meet which the report states "more perfect protection to the structure is required" than that before referred to.

The probable displacement of steel members when ramming the concrete needs also to be considered.

For buildings above described, even Mr. Macdonald will doubtless admit that a minimum cover of 1½ in. to 2 in. for floor slabs, according to their area, load and position, and 3 in. for beams, girders and columns, is needed to secure reasonable protection against serious deflection or collapse under the action of fire, and for providing the effective "passive resistance," admitted to be of the greatest importance.

The concrete composing this cover should be made with an ample quantity of good Portland cement, and aggregates of suitable material and size.

COVERING REINFORCED CONCRETE WITH PROTECTIVE COVERINGS.

Capt. Sewell, of the United States Army Engineers, whose experience with regard to concrete structures under fire is most extensive, recommends, in a report to his Government, a minimum thickness of 4 in. in front of all metal work, and favours the use of the right kind of burned clay for the outer portion of such protection.

There is no practical difficulty in providing and fixing porous terra-cotta, moulded so as to be securely keyed into the concrete as this is placed in position, and doubtless the best results would be secured by such an arangement which would allow of the use of "natural aggregates" giving the greatest strength, and also afford efficient protection against powerful streams of water, which, in the event of fire, it is not possible to prevent striking structural supports. Although a fireman would not knowingly direct a jet against such supports, it is frequently impossible for him to see them on account of smoke. This appears to have been the case at Newcastle, referred to by Mr. Macdonald, where it is admitted that the concrete was much eroded by streams of water.

Referring to Mr. Macdonald's remark on the thickness of divisional structures, it should be noted that floors simply separate portions of the same building, and can be readily flooded with water, effectually preventing serious increase of temperature on their upper surfaces, but walls separate distinct buildings, and their surface cannot be flooded like floors; for this and structural reasons it is necessary for due protection that party walls should be much thicker than floors.

A structure in concrete 4 in. thick, containing a large proportion of steel, would be much less fire resisting than a similar structure 5 in. thick containing a smaller proportion of steel. This is shown by the result of one of the recent official tests of the

British Fire Prevention Committee with a deep concrete floor having a very small proportion of steel reinforcement, illustrated by *Figs.* 2 to 4, and descriptions annexed.*

POSITION OF THE FIRE OFFICES.

Fire offices are not likely to encourage by a maximum allowance slight constructions for buildings intended to be fire-resisting, to enable promoters of such buildings to compete with cheaper form of construction not claiming to be fire resisting.

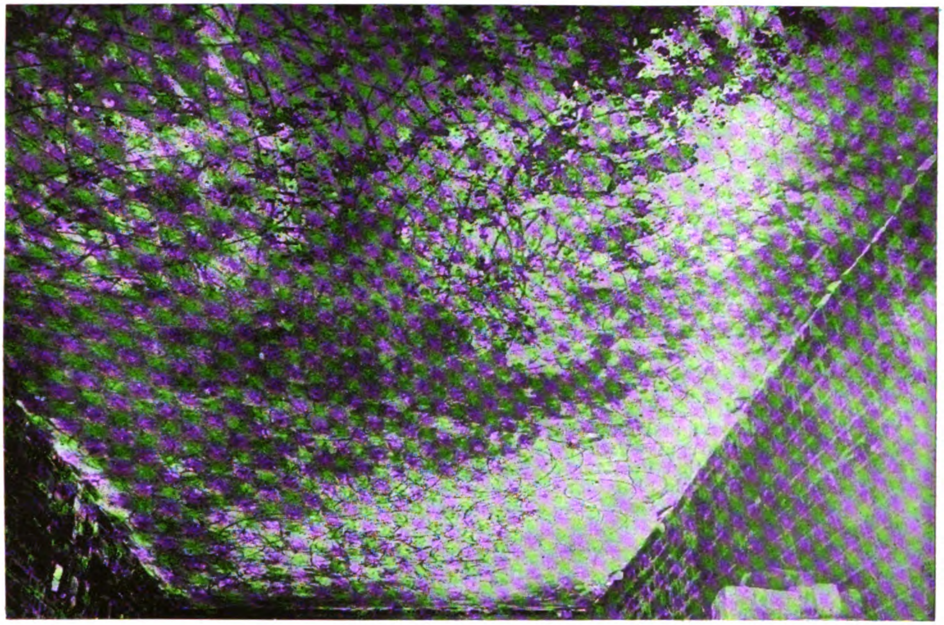


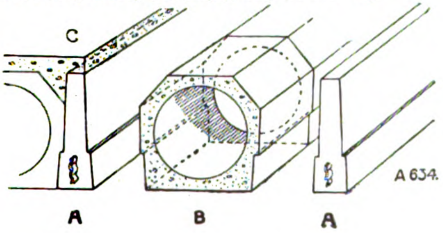
FIG. 4. FLOOR ON THE HERBST SYSTEM (*after test, January* 30, 1907.)

If a reliable fire-resisting building is desirable, it is worth paying for, apart even from the question of the amount that would be saved under the head of fire insurance.

Architects and building owners will always have every assistance from the Fire office with which they may intend to insure, who will give information as to deductions for improved methods of construction conforming to different standards of fire resistance.

---

* Floor constructed by W. Herbst (Berlin), now known as the Armoured Tubular Flooring Co. Test of January 30th, 1907, Report No. 119.



The floor comprised reinforced concrete webs with intermediate hollow concrete blocks (or tubes) the whole being covered by concrete, the total thickness of the floor being 11 in., with an additional 1 in. of plastering to soffit.

The concrete was composed of 1 part Portland cement, 2 parts shingle, passing a ¾ in. mesh, and 1 part sand. The tubes were 1 part Portland cement, 5 parts sand, and 7·5 parts coke breeze. The covering concrete was 1 part Portland cement and 3 parts shingle. The "Hilton Anderson" brand of Portland cement was used.

The reinforcement was embedded in the web about 1 in. above the soffit, and comprised corrugated wrought-iron bars 1¾ in. by 5-16 in., the soffit being coated with special fire-resisting plastering 1 in. thick.

The floor under test had a span of 10 ft. by 22 ft. 3 in. long, and the load was 2½ cwt. per ft. super. The time allowed for drying and setting was 47 days (winter).

The floor was under fire test for four hours, at temperatures ranging to over 2,000 deg. Fahr., followed by the application of water from a steam fire engine for five minutes.

The maximum deflection during test was ½ in. and the permanent deflection 7-16 in.

RESEARCH WORK AND GOVERNMENT SUPPORT.

General research work and accumulation of data on fires and fire-resisting construction is of the utmost importance. To secure public confidence, this work should be undertaken by an independent committee representative of both the public authorities and the technical professions, such as the British Fire Prevention Committee having Government support. But such Government support should be materially increased so as to allow of exhaustive investigation.

The United States Government Departments are supporting investigations on these questions with grants such as £20,000 per annum alone for tests generally with structural materials. It is quite time the British Government also did something substantial in this direction, instead of limiting itself to merely nominal contributions. It is true the annual fire loss of Great Britain has been materially reduced by propaganda and work, such as that of the British Fire Prevention Committee. But it still exceeds 10 million pounds per annum constituting a national loss. Thus a few thousand pounds applied to fire tests with reinforced structures, steel frame and concrete buildings, etc., would by no means be ill spent.

APPENDIX.

[*The following should be interesting reading in connection with the foregoing article.*—Ed.]

Original Resolution of the International Fire Congress at Milan, 1906:—

That the Congress considers that no reinforced concrete construction should be permissible in buildings intended to be fire-resisting unless the aggregate be most carefully selected and applied in such a manner as to give substantial protection to all metal parts.

That it is advisable where reinforced concrete is intended to be fire-resisting that every portion of the metal rods or bars contained therein be covered by not less than 2 in. of concrete, the aggregate of which must be able to pass through a sieve of not more than 1 in. diameter, and that Portland cement of great fineness only be used.

That where feasible all external angles should be rounded.

Any angle iron needed for mechanical protection should be held in position independently of the concrete.

The Resolution of the International Congress of Architects, London, 1906:—

That where reinforced concrete is intended to be fire-resisting the greatest possible care must be taken as to the nature of the aggregate and its size, and also as to the protection of the steel.

The Proposal of the Reinforced Concrete Committee, London, 1907:—(Abbrev.)

Floors, walls, and other constructions in steel and concrete formed of incombustible materials prevent the spread of fire in varying degrees according to the composition of the concrete, the thickness of the parts, and the amount of cover given to the metal.

Experiment and actual experience of fires show that concrete in which limestone is used for the aggregate is disintegrated, crumbles and loses coherence when subjected to very fierce fires, and that concretes of gravel or sandstones also suffer, but in a rather less degree.[*] The metal reinforcement in such cases generally retains the mass in position, but the strength of the part is so much diminished that it must be renewed.

Concrete in which coke-breeze, cinders or slag form the aggregate is only superficially injured, does not lose its strength, and in general may be repaired. Concrete of broken brick suffers more than cinder concrete and less than gravel or stone concrete.

For main beams covering of 1½ in. to 2 in. of concrete over the metal reinforcement appears from experience in actual fires to afford ample protection to the structural parts. In floor slabs the cover required may be reduced to 1 in.

All angles should be rounded or splayed to prevent spalling off under heat.

More perfect protection to the structure is required under very high temperature, and in the most severe conditions it is desirable to cover the concrete structure with fire-resisting plastering which may be easily renewed.

Columns may be covered with coke-breeze concrete or other fire-resisting facing.

The Rules of the Fire Offices Committee, London, 1905.

Concrete may be composed of sand and gravel that will pass through a ¾-in. mesh, or of the other materials mentioned in the Rule, but in any case the cement used must be Portland (equal to the British Standard Specification of December, 1904),[†] in the proportion of 6 cwt. of cement to each cubic yard of concrete. . . .

All structural metal work must be embedded in solid concrete, so that no part of any rod or bar shall be nearer the face of the concrete than double its diameter, such thickness of concrete must be in no case less than 1 in., but need not be more than 2 in.

---

[*] The smaller the aggregate the less the injury.

[†] Since superseded by Specification of 1907.

REINFORCED CONCRETE IN RESERVOIR CONSTRUCTION.

By E. R. MATTHEWS, A.M.Inst.C.E., F.R.S.Ed., F.G.S.,
Borough Engineer of Bridlington.

In our issue No. 3, Vol. I., we dealt with the application of reinforced concrete for water mains, in an article from the pen of Mr. R. H. Wyrill, M.Inst.C.E., Waterworks Engineer, Swansea. Such reinforced concrete pipes have not only been laid down in Swansea, but are now being laid down in Norwich under the supervision of the City Engineer, Mr. A. E. Collins, M.Inst.C.E.

The following article by the Borough Engineer of Bridlington, Mr. Ernest R. Matthews, A.M.Inst.C.E., deals with another application of reinforced concrete for waterworks engineering—namely, its use in reservoir construction—and there is no doubt that, as in the case of large pipes, so in reservoirs, efficiency combined with substantial economies can here be obtained by employing reinforced concrete in a suitable manner.

We are afraid, however, that the advantages of this material have not yet been fully realised in this country, though America, France and Germany have long given us a lead, and have more particularly benefited the ratepayers of the smaller municipalities by its use.—ED.

REINFORCED concrete in reservoir construction has not been so extensively used in this country as in America. The author, however, believes that we are fast approaching the time when English engineers will realise that this form of construction is the best, both from an engineering and from an economical standpoint. It is his opinion, speaking from a very extensive use of this material in various classes of engineering work, that this form of reservoir construction possesses the following advantages :—

(1). Economy in Cost.—This is one of the principal reasons why reinforced concrete has been so largely used in America, especially in the covering-in of service reservoirs and in the construction of the floor of reservoirs, for both of which purposes the author claims it is admirably suited. He says that reservoir roofs may be constructed of this material much cheaper than by the English methods of construction—namely, brick arches, segmental arches with concrete on top of same, or girders and concrete. The author has used re-inforced concrete in roof construction largely, and his opinion is that it is an ideal material to use for the roofing-in of covered service reservoirs, and that it is the most economical.

As to its use for covering reservoir bottoms, he says that, where the bottom of a reservoir has to be formed in bad ground or on an uncertain foundation, as is so often the case, reinforced concrete is the very best material to use, and the cost of same under these conditions is much less than that of ordinary concrete, owing to the fact that the thickness of the concrete floor may be so considerably reduced if reinforced concrete is used. The thickness of concrete of which reservoir floors in this country are usually formed varies from 1 ft. to 2 ft., according to the nature of the ground and the depth of water in the reservoir. By using reinforced concrete, however, this thickness may safely be reduced to 6 in. where the water does not exceed, say, 10 ft. in depth, and 9 in. where there is a greater depth of water, so that a great saving in cost is effected.

(2). Cost of Maintenance.—The cost of maintenance of a reservoir entirely constructed of concrete and reinforced concrete is practically nil, and this fact, together with the economical cost of construction, should be taken very seriously into consideration by waterworks' engineers when designing reservoirs.

(3). Rapidity of Execution.—The author's experience is that any engineering work constructed of these materials can be executed much more rapidly than by the employment of any other material, such as brick or stone.

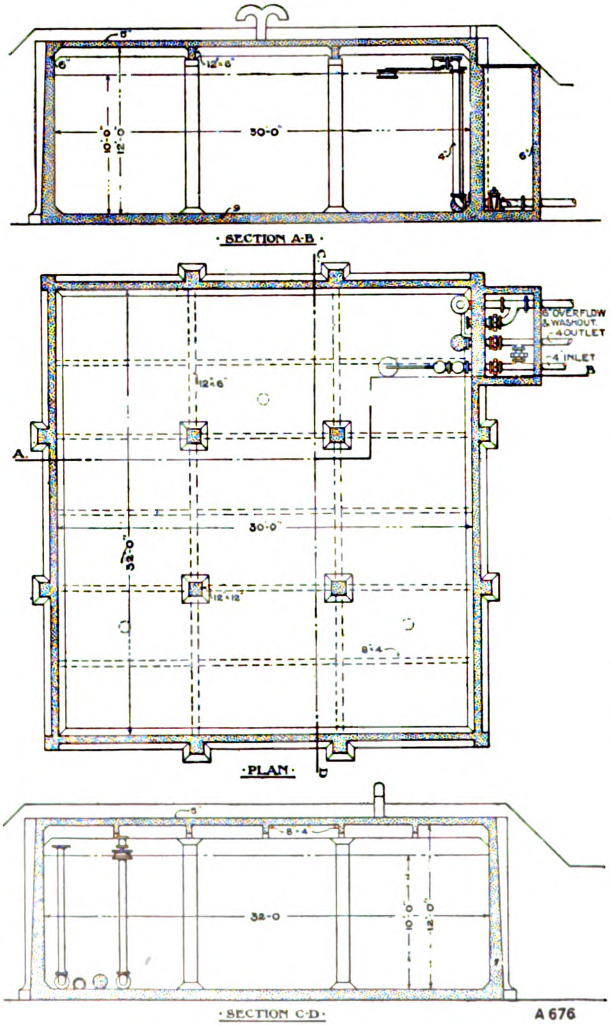


Fig. 1. Doscomb Reservoir (constructed in Reinforced Concrete).

(4). Hygienic Value of Reinforced Concrete.—It will be generally agreed that concrete and reinforced concrete are ideal materials to use in reservoir construction from the point of view of their hygienic value, for this is known to be very great.

(5). Saving of Space.—By using reinforced concrete in the construction of the floors, walls, and roofs of covered service reservoirs a great saving of space occurs, the whole structure being lighter than when constructed of the usual English design.

(6). Reservoir Increases in Strength with Age.—This is a very important point, for while the best brick lining to the walls and roof of a reservoir deteriorate, concrete is one of the very few materials which improve in strength and hardness with age. This, the author claims, is a point which does not receive sufficient consideration.

(7.) No Joints.—Another advantage is that a reservoir built entirely of concrete, or reinforced concrete, or both, has no joints.

The seven points which the author has given in favour of the use of reinforced concrete in the construction of covered reservoirs might be supplemented by others, but he considers that these are sufficient to show that this material should be used in all structures of this kind.

Before proceeding to give examples of the use of reinforced concrete in reservoir construction, the author desires to say a word or two respecting an objection which has been raised to the use of this material for this purpose.

Reinforced concrete has been objected to on the grounds that in course of time the steel bars or other reinforcement, if subjected to continuous damp, as would be the case in reservoir construction, lose much of their strength. The author would state that his experience causes him to entirely disagree with this; in fact, it has been proved so often that oxide of iron cannot exist in contact with cement, that this objection can be dismissed forthwith.

Not only so, but experience shows that rusty bars embedded in concrete will in a very short time become deoxidised by the formation of ferrite of calcium.

EXAMPLES OF REINFORCED CONCRETE IN RESERVOIR CONSTRUCTION.

The author gives three examples of the use of reinforced concrete in reservoir construction—two English and one American example.

Two British Examples.

Fig. 1 is a plan of the Doscomb Reservoir, which is being constructed for the Petersfield Rural District Council, and which has been designed by Mr. Harry W. Taylor, A.M.I.C.E., of Newcastle-onTyne, to whom the author is indebted for the plans of this reservoir.

The reservoir, as will be seen, is constructed of reinforced concrete throughout. Its dimensions are 32 ft by 30 ft. by 10 ft., with a capacity of 60,000 gallons. The special features about this reservoir are the thin walls and that the roof is only 5 in. in thickness, and is supported by reinforced concrete beams 12 in. by 6 in. and 8 in. by 4 in. The columns are also of reinforced concrete, 12 in. by 12 in., and the floor is formed of the same material.

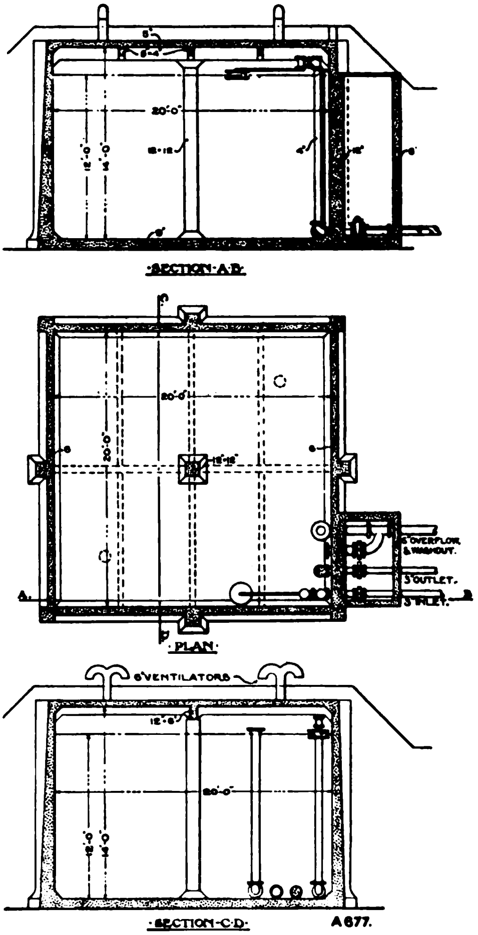


Fig. 2. Hill Side Pressure Maintaining Tank, Liss Waterworks (constructed in Reinforced Concrete).

Fig. 2 illustrates a smaller reservoir or tank—namely, the Hill Side Pressure Maintaining Tank, designed by Mr. Taylor for the Petersfield Rural District Council, in connection with their Liss Waterworks. Its dimensions are 20 ft. by 20 ft. by 12 ft., with a capacity of 30,000 gallons. This is of similar construction to the reservoir before-mentioned, and fully illustrates how economically reinforced concrete may be used in structures of this kind.

In both cases the walls are supported by buttresses at intervals, and the reinforcement throughout consists of "indented bars."

An American Example.

Fig. 3 illustrates the use of reinforced concrete in covered reservoir construction in America, and is one of the best examples to be found. The Louisville Reservoir, a portion of which is here illustrated, is constructed throughout of this material, a brief description of the reservoir and of the steel reinforcement being as follows:—

The roof is of the groined-arch method of construction, the arches being approximately 19 ft. span and 3.8 ft. rise, the radius of the arc forming the intrados being 13.775 ft., and that of the extrados 32.256 ft. The thickness of concrete at the crown of arch is 6 in. and above piers 3 ft. The reservoir is 460 ft. by 392 and 394 ft. in size, and has a capacity of 25,000,000 gallons. The columns, or piers, are about 3.4 ft. diameter and 21.11 ft. in height, and are placed 22 ft. apart, centre to centre. The whole of this interesting construction has been carried out in Portland cement concrete 1 : 2 : 4.

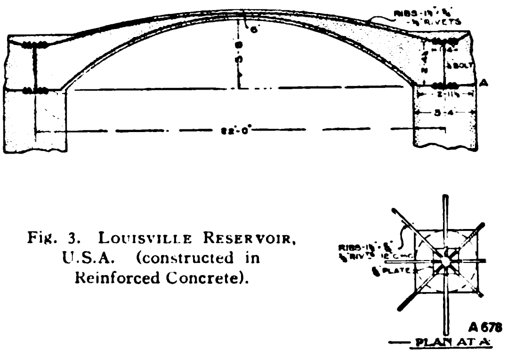
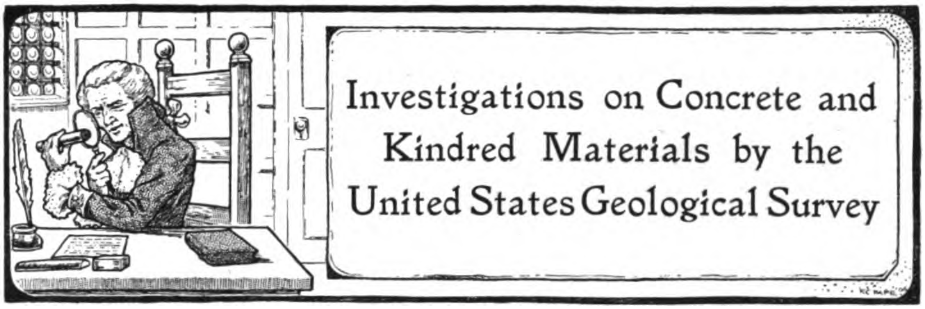


Fig. 3. Louisville Reservoir, U.S.A. (constructed in Reinforced Concrete).

Embedded in each of the arches are $1\frac{1}{2}$ by 5-16 in. steel ribs, resting upon each pier. These ribs are inserted in eight half-piers; four of these are placed at the groins of the arch and four midway. Two steel plates, 16 in. square by 5-16 in. thick, are placed in each pier and in the side division walls of the reservoir, and the ribs meet upon and are riveted to these. The plates are $28\frac{1}{4}$ in. apart vertically, tied together in the middle by a $\frac{1}{2}$ in. rivet. In order to make sure that the steel ribs adhered to the concrete, $\frac{3}{8}$ in. rivets were placed through the middle of the rib about every 12 in. apart.

The area covered by the groined arches is 180,740 ft. super. The groined arches are 340 in number, 270 of which are square, 22 by 22 ft. span between centres of columns, and 70 arches are in one direction of 22 ft. span, and at right angles thereto of variable span—both greater and smaller than 22 ft.—owing to the quadrangular plan of the reservoir not being square, but a trapezoid. The total cost of this reinforced arched covering was 2s. 6d. per super foot.

The author is of the opinion that both the reinforced concrete roof and the piers in the Louisville example are unnecessarily strong, but he has given a description of this reservoir in order to show that reinforced concrete is the material of which some of the principal modern covered reservoirs in America are constructed.



Investigations on Concrete and Kindred Materials by the United States Geological Survey

By **RICHARD L. HUMPHREY**, M.Am.Soc.C.E., Philadelphia

(Engineer in charge of the Structural Materials Division, United States Geological Survey).

Last year we referred to impending American investigations of structural materials, and concrete in particular, which were to be conducted by a voluntary Sub-committee, the expense of the experiments to be substantially supported by the United States Government.

We have now received from Mr. Richard L. Humphrey, the well-known American authority on structural materials, an interesting communication as to the inquiry and the testing arrangements made.

We have also received, by the courtesy of the Department of the Interior, Washington, the illustrations presented herewith.

The inquiry, which is being conducted in the United States, is of the highest importance to the development of concrete and reinforced concrete, but even more particularly to the latter form of construction and to that of the hollow concrete block.

We shall from time to time deal with the investigations as they proceed, and we would call the special attention of our own Government departments to the liberal manner in which inquiries of this description receive Government support, not only in the United States, but in practically every Continental country.—ED.

WITH the problems arising from the growing scarcity and consequent increase in the price of wood, principally lumber used in building construction, the search for a desirable substitute becomes a matter of prime importance and justifies the work now being done by the United States Geological Survey at its structural materials testing laboratories at St. Louis.

The increased use of concrete in many forms during the past few years, especially for building purposes, has created a great demand for information regarding the structural value of this material. For a number of years limited investigations designed to obtain this information have been carried on by a number of investigators throughout the country, but no serious attempt at co-operation in this work had been made until a few years ago, when the United States Geological Survey, recognising the need of information and co-operation, procured a small appropriation for making tests of structural material and invited various technical societies to take part in the work.

A committee, called the Joint Committee on Concrete and Reinforced Concrete, was invited to assist in outlining the work at the laboratories. This committee is composed of members of the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway Engineering and Maintenance of Way Association, and the Association of American Portland Cement Manufacturers. The leading professors of engineering from almost all of the large colleges in the country are members of this committee, and they exercise general supervision over the work.

An Advisory Board composed of leading engineers throughout the country was at once created and has had general supervision of the work.

Tests are being carried on to determine the value of different sands, stones, and other materials used in the manufacture of concrete. The material is shipped from all parts of the country by geologists connected with the work and a complete record of the material is sent in by them. At the laboratories this material is made into mortar and concrete by using the different percentages ordinarily employed in practical work and following as closely as possible practical conditions.

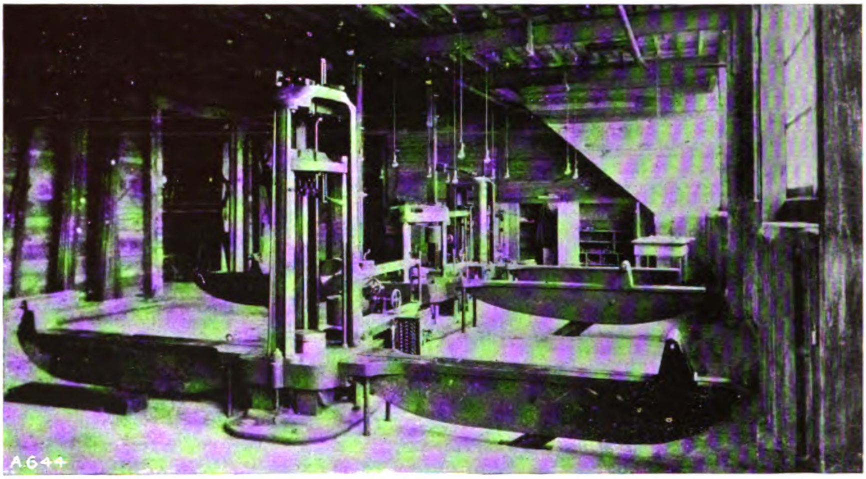


FIG. 1. Three concrete-beam testing machines.

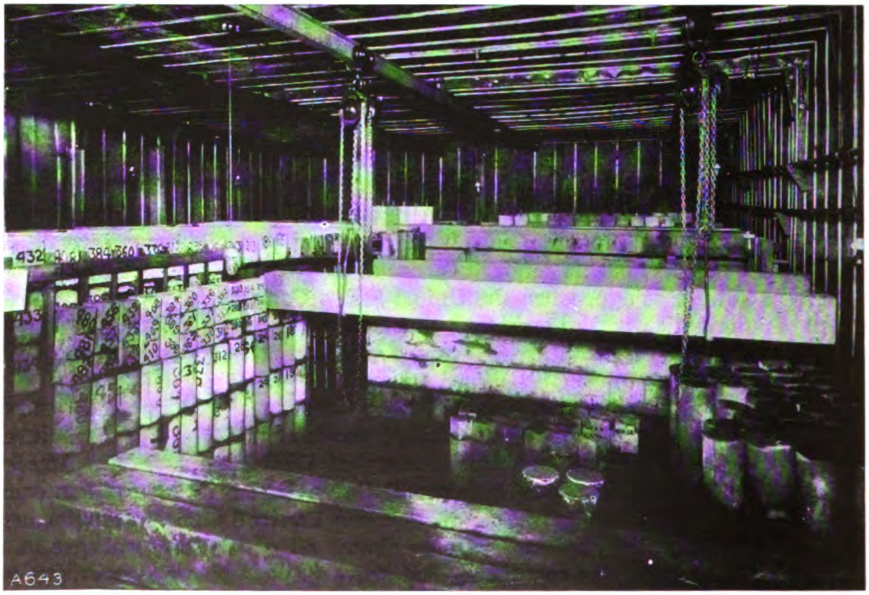


FIG. 3. Room in which concrete beams are stored.

In addition to the study of the constituent materials of mortars and concretes, structures of various kinds similar to those used in buildings are made and tested.

The equipment of the laboratories at St. Louis for carrying on this work is very complete. In addition to all needed smaller apparatus there are four testing machines of 200,000 lb. capacity and one of 100,000 lb. capacity, suitable for testing beams and other structures used in buildings. These machines will test beams up to 20 ft. in length and are equipped to make tests of the different materials used in construction work. Three of these machines used in the beam division are shown in *Fig.* 1.

In addition to the above machines a very large machine, having a working capacity of 600,000 lb., will in a few weeks be installed at the laboratories at St. Louis. As far as known at this time there is only one other machine in the United States similar to this. This machine will make it possible to test columns, beams, and, in fact, all the different kinds of construction material now used. It will test very large reinforced concrete girders up to spans 30 ft. in length and concrete columns up to 30 ft. in length.

The value of such tests as these is readily apparent, since their results can be applied directly to practical work. A very serious objection to the use of results obtained in tests made by private investigators is due to the fact that the tests were applied only to small specimens, not nearly approaching in size the parts or pieces used in actual construction. Heretofore it has been necessary to consult the results of these small tests in order to have some basis for design, but it is now clearly recognised that the best results can be obtained only from tests made on members as large as possible, or at least on pieces as large as those ordinarily used in structural work.

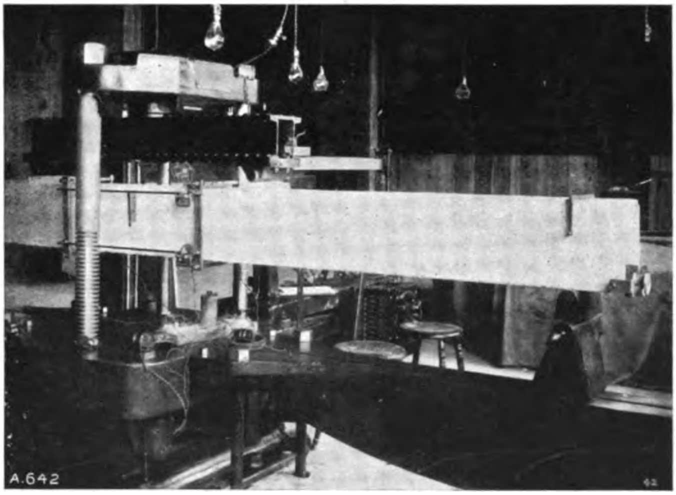


FIG. 2. Testing a 13 ft. concrete beam.

All the concrete used at the laboratories is mixed in three Chicago cube concrete mixers, each of which is mounted on skids, geared to a motor and equipped with charging hopper. One of these mixers has a capacity of 1 cubic yd. and the others will contain ⅓ cubic yd. each. After the concrete is mixed it is carefully tamped in moulds to form the different pieces on which the tests are made, such as cylinders, cubes, and beams.

The laboratory also uses five hollow concrete block machines, used for making concrete blocks similar to those used in actual construction, and the several different divisions—the constituent materials division, the beam division, the concrete block division, the permeability, the shear and tension, and the chemical division—are equipped with all apparatus necessary for conducting their tests.

Although reinforced concrete is used to a remarkable extent at the present time, and both concrete and reinforced concrete construction is becoming more and more popular every day, it is evident to anyone familiar with construction work that these materials will be more generally employed within the next few years. Many engineers are prejudiced against the use of concrete and reinforced concrete, but this prejudice is rapidly being removed by the obtainment and publication of reliable data regarding this material. Without doubt, in a very few years, when most of the principles underlying the use of concrete and reinforced concrete have been fully established from tests and investigations, there will be little prejudice against the use of concrete; the present prejudice evidently being due to lack of information.

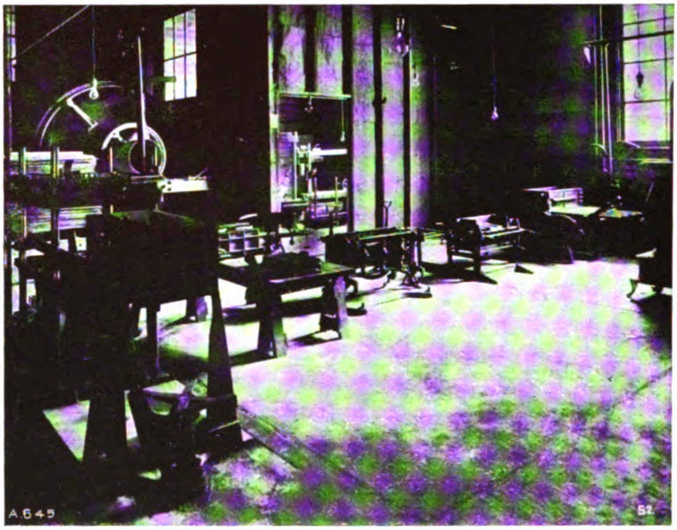


FIG. 4. Cement block machine.

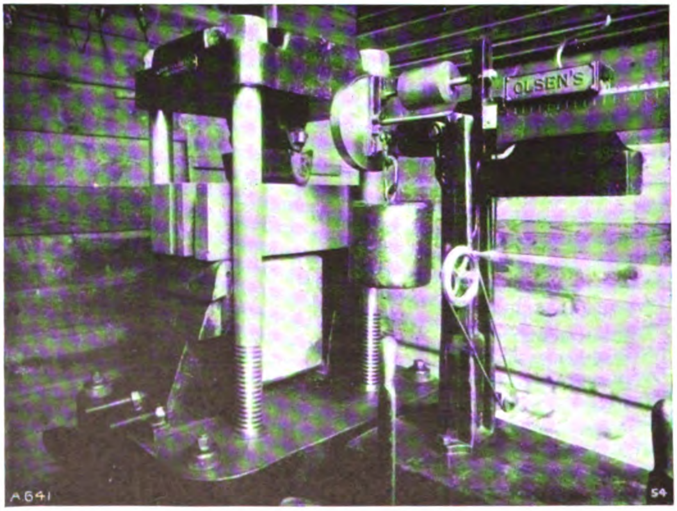


FIG. 5. Block testing machine.

The longest beam thus far tested in the beam division has been 13 ft. in length. Beams of this length tested are made without steel, that is, of solid concrete beams, and also with varying proportions of steel, ranging from very small percentages up to 3 per cent. A full-size beam in the testing machine is shown in *Fig.* 2; the load is applied at the top of the beam at points 4 ft. from each end. The men conducting the tests watch the beam very closely while it is in the testing machine, and examine its surfaces with magnifying glasses in order to locate the fine cracks as they appear. In the beginning a load of about 5,000 lb. is applied and the machine is stopped with this load on the beam. After the observers have examined the beam carefully and made a record of the cracks appearing at that time, the load is increased, and after every 1,000 lb. additional the beam is again examined until the maximum load is applied.

In a very large number of tests the beam shows no cracks that are visible to the eye until the maximum load is reached, when the steel reaches its elastic limit and begins to stretch fast, this result ending the test. The cracks that appeared on the beam and the loads at which these cracks appeared are recorded by photographs.

In beginning tests of reinforced concrete simple round rods were used, as it was thought that more uniform results could thus be had than if any of the patented systems were used. After a complete series of tests with the round rods has been made it is proposed to take up tests of the different forms of bars that are used in practical work, and the results will be published from time to time by the Geological Survey. Tests will be made of beams ranging from 6 to 12 ft. in length, and because of longer span will be tested later, if necessary, in order to get results that can be applied to almost all practical conditions.

The concrete used in the different beams tested, as described above, is moulded into cylinders and cubes, which are tested in order to get the direct strength of the concrete. These cylinders and cubes are all tested at different ages, generally at ages of 7, 28, 90, 180 and 360 days. The cement, sand, stone, gravel, or other material composing the concrete is carefully proportioned by weight, the correct percentage of water is used and the whole mass is placed in a mixer and thoroughly mixed. It is then deposited very carefully in moulds or forms which, after 24 hours, are removed. The concrete is then moved into a storage room, shown in *Fig.* 3, and is there sprinkled with water three times each day. Each test piece is numbered on a card index, which tells where information relating to the test piece can be found, and also indicates the dates on which the different pieces are to be tested.

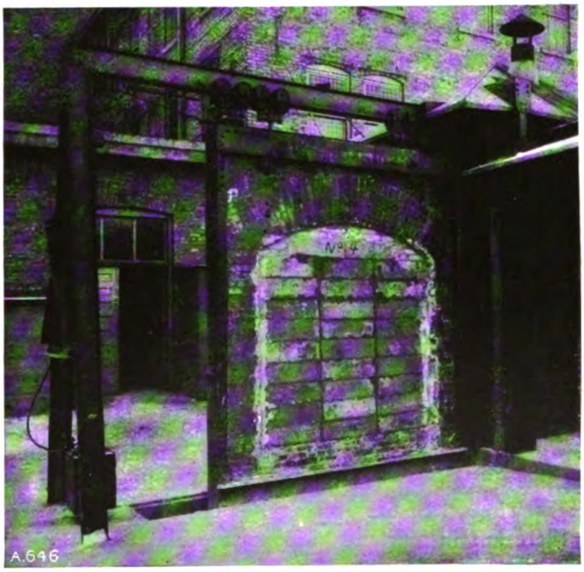


FIG. 6. Testing fire-resisting qualities of concrete, etc.

A branch of the work that should be of interest to everybody, especially the small home-builder, is the investigation of cement building blocks. Many houses are now built of cement blocks in preference to wood, because generally cement block construction is cheaper and better than wood, since it is fire-resisting, more durable and less expensive to maintain.

All the cement blocks used in these investigations are mixed in the concrete block machines shown in *Fig.* 4. The concrete is mixed in a $\frac{1}{3}$ cubic yd. cubical concrete mixer and deposited on the floor of the testing room. It is then shovelled into the hollow block machines and compacted very firmly in the forms. Varying proportions of concrete, sand, and stone are used in order to determine the relative value and economy of using different mixtures. Some blocks are made of wet concrete, others of concrete very dry, and still others of concrete having a consistency medium between wet and dry. In actual practice concrete blocks made from comparatively dry concrete is usually preferred by the manufacturers, for these blocks harden quickly and the forms may be removed almost as soon as all the concrete is placed in the machine. By this practice it is possible to use the same machine for making a large number of blocks each day, whereas when wet concrete is used the blocks must remain in the machine for a much longer time before they can be removed. When the concrete blocks are removed from the forms they are placed in the storage room and tested at different ages. The storage room used for concrete blocks is similar to that shown in *Fig.* 3. Cylinders are also made from the same concrete that is used in the blocks, and the results of tests of the cylinders and of the blocks establishes a relation between the strength of the concrete in the cylinder and that of the concrete in the block.

Concrete blocks are tested at the laboratories in two different ways : first as shown in *Fig.* 5, to see how much of a centre load each block will stand. Although blocks are not actually subjected to a load of this kind in practice, the results of this test make it possible to compare the relative values of different building blocks. Secondly, after the block has been broken at the centre by this load, each half is placed in the testing machine and crushed, in order to find the crushing strength of the block. The results of this crushing test show how much pressure similar cement blocks will stand when used in actual building construction.

The results of the great fires at San Francisco and at Baltimore demonstrated very clearly the fact that modern buildings are not so nearly " fireproof " as they should be and as they can be made. The lack of fireproofing in the past has been due somewhat to the reluctance of owners to add a small percentage to the cost of their buildings by properly fireproofing them. The failure to employ " fireproof " construction more generally, however, was due in part to the fact that proper information was lacking.

The art of fireproofing has been developed rapidly within the last few years, but there is still much to be done, especially in relation to the fire-resisting properties of concrete. In order to obtain information to meet these needs a series of minor fire tests are being carried on at the Fire Underwriters' Laboratory at Chicago.

For this purpose a hanging door having a steel frame and a 1.-ft. wall of fire-brick inside of it is used. At the centre of this frame there is an arched opening of about the size of an ordinary door. For the fire tests this opening is built up successively with different materials, ordinary building brick, fire-brick, hollow tile blocks, the different kinds of cement building blocks, stone, concrete, and terra cotta. When the opening is filled with cement blocks it has the appearance shown in *Fig.* 6. After the opening is filled, a flaming gas jet is played all over the door for a long time, and when the heated surface is very hot the gas is turned off and the door allowed to cool. In some tests the cooling takes place slowly, in others a stream of water is played on the door immediately after the gas is turned off, in order to reproduce as nearly as possible the actual conditions in a fire

It is most desirable that the public should be informed as to fire-resistive qualities of the various classes of building materials, and it is expected that the work being done by the United States Geological Survey will also furnish some useful additional information on this subject.

A Warehouse of Reinforced Concrete in Dundee.

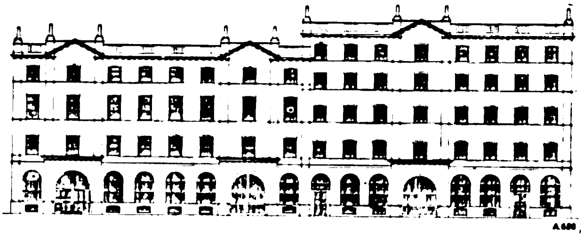


Fig. 1. General View.

The great fire at Messrs. Watson's warehouse in Dundee must be in the recollection of many.

Messrs. Watson have now reconstructed their warehouse, adopting the most modern form of construction available, namely, that of reinforced concrete, and in publishing the enclosed description of their new building, we must add that it is just for buildings of this description that we consider reinforced concrete to be practical and economical.—ED.

By the courtesy of the architects, Messrs. Johnson and Baxter, of Dundee, and the structural engineer, Mr. L. G. Mouchel, of Westminster, we are enabled to present in this number drawings which illustrate the architectural and constructional features of the fine new buildings erected in reinforced concrete at Seagate, Dundee, for Messrs. James Watson & Co., Ltd., the well-known whisky distillers, the work being executed on the Hennebique system.

Before entering upon the description of the new warehouse we ought to state that the former buildings on the same site were destroyed by fire, when the large amount of spirit on the premises added very greatly to the fierceness of the flames, and considerable quantities poured out into the streets, much to the delight of those inhabitants who were not total abstainers, although it was unhappily the case that several men, not able to appreciate the maxim to the effect that "enough is as good as a feast," afterwards succumbed to the effects of alcoholic poisoning. These facts are mentioned for the purpose of showing the necessity for quite special features of construction in the design of the new warehouse.

To begin with, Messrs. J. Watson & Co. determined that every part of the buildings should be of the most approved type of fire-resisting construction, and having inquired into the safety offered by reinforced concrete in this particular, they decided to make use of the new material for the construction of the floors, roofs, stairways, lift wells, and interior columns, the outer walls being built of brick.

Then the firm decided that the safety of the stores should be further guaranteed by the construction of main partition walls isolating the building into three blocks, intercommunication being possible only through fire-locks, arranged something after the principle of the air-locks employed in subaqueous tunnelling work with pneumatic pressure.

Finally they made it a *sine qua non* that some approved means should be provided for drawing off spirit from the various floors in case of fire, so as to avoid feeding the flames with highly inflammable material and to prevent the spirit from flowing into the public streets, as happened on the occasion of the previous fire. These conditions were satisfied by the system of ducts, which will be described later.

Fig. 1 is an elevation on Trades Lane. These drawings will enable readers to see that the architectural treatment is simple and appropriate to the nature of the warehouse. *Fig.* 2 is a plan of the first floor, this being fairly typical of all five storeys of the building, the greatest length of which is 250 ft. and the greatest breadth 130 ft. The plan shows that the floor system is divided for the greater part into panels measuring about 12 ft. square, an arrangement that could not be preserved throughout because of the irregular shape of the buildings.

Another deviation from symmetrical treatment is to be found in the duplicate system of panels as constituted in one case by the longitudinal and transverse rows of beams, and in the other case by the rows of columns in places where these do not coincide with the rows of beams.

It is hardly necessary to give sections of the columns, beams and floor slabs of the Dundee stores, especially as the dimensions of the beams vary in a very marked degree to suit the spans and loads. This will be clear when it is stated that in the first floor alone there are eleven distinct sizes of beams each having its own special arrangement of reinforcing bars.

Still, there are some unusual types of beam construction which deserve illustration. These were called for by the two sunk troughs or gutters lettered YY and ZZ on the plan.

Fig. 3 is a section of the trough YY where the sunk portion of the floor slab is clearly to be seen. For the intermediate support of the trough it was necessary to design the beam W_2 depicted in *Fig.* 4, which represents an interesting example of the Hennebique truss construction applied to a fish-bellied girder. The other trough ZZ and the special girders designed for its support are very much like those belonging to YY and so need not be illustrated.

We come now to the complete system of ducts provided throughout the stores for the rapid evacuation of whisky from all the floors in case of need. On *Fig.* 2 are shown the positions of the ducts in the three separate sections of the building, these ducts being five in number on each floor. *Fig.* 5 is a vertical section showing ducts A and B.

At the commencement of each duct there is a long opening in the floor intended to facilitate the collection of spirit from casks that have been broached, the cross section in this part being shown in detail by *Fig.* 6. Beyond the opening comes the closed portion of the duct where the cross-section is like that represented in the detail drawing, *Fig.* 7, but the ducts are enlarged at the end with the object of enabling the spirit to pour more readily into the lift well, which is intended to be utilised as a vertical shaft. The same arrangement applies to the ducts of type C.

The positions of the ducts of the type B, B′ and D are marked on *Fig.* 2. All the ducts B and B′ discharge into a special vertical shaft conveying spirit to ground-floor level. Those of type D discharge into a common vertical shaft extending downwards from the third floor to the first floor and thereafter through a wide-mouthed spout into the large opening provided in the ground floor of the warehouse. *Fig.* 8 is a typical section of the vertical discharge shafts.

All the ducts and shafts described are built in reinforced concrete monolithic with the other parts of the construction. Perhaps it may be as well to explain that no attempt will be made to preserve the spirit discharged in the event of fire, because if the outbreak were so serious as to necessitate the wholesale broaching of casks all the work of the scientific blender would at once be undone and the flavour of the whisky ruined by contact with smoke, etc., to say nothing of the

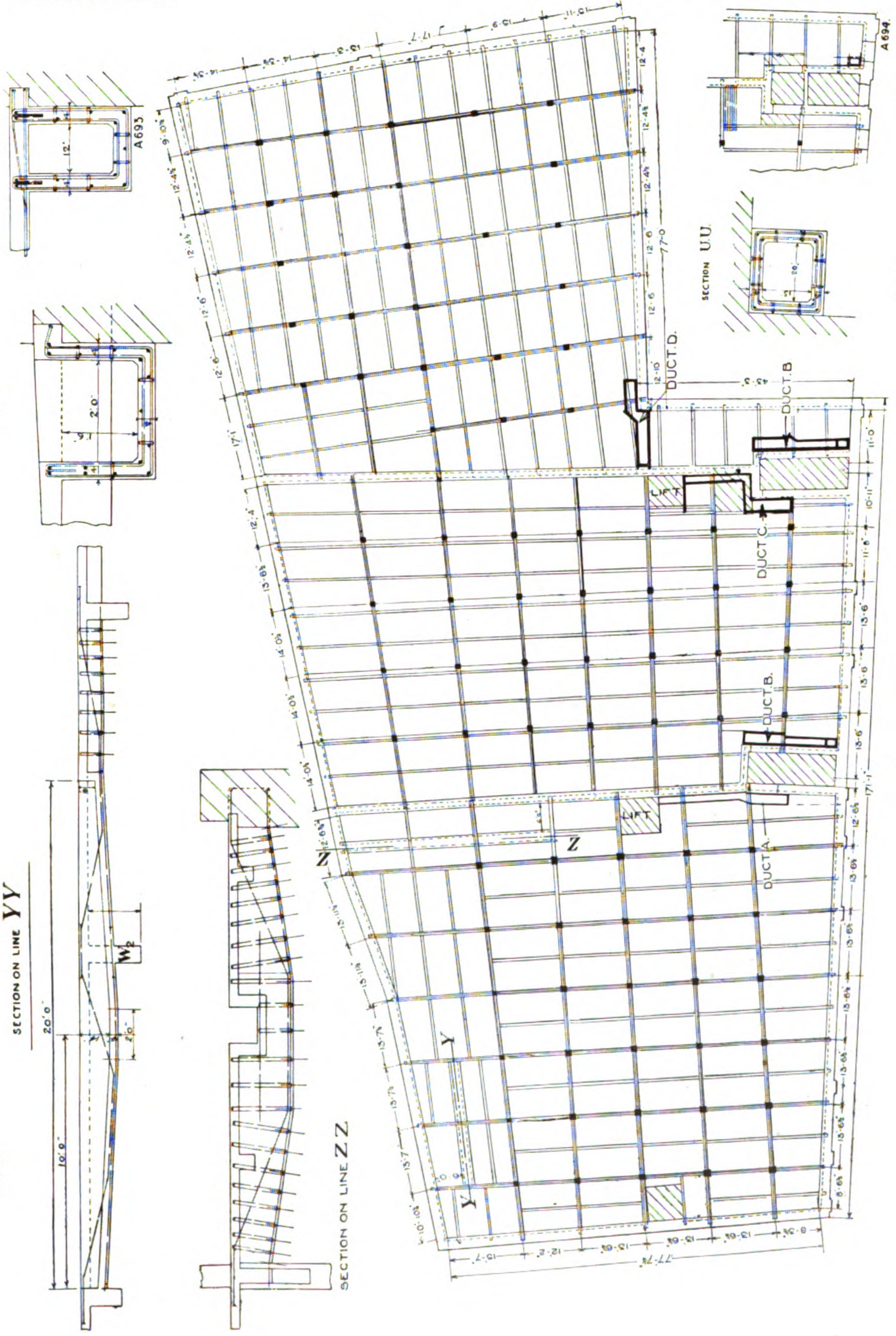


Fig. 7.

Fig. 6.

Fig. 3.

Fig. 4

Fig. 9.

Fig. 8.

Fig. 2.

Plan and Details of Reinforced Concrete Warehouse, Dundee.

probability that some of the spirit might catch fire. Therefore the whisky will find its way to the fireproof basement of the stores whence it will be removed by drains from the proximity of the buildings.

The fire locks giving means of communication between the three stores are shown in plan in *Fig.* 2. An enlarged plan of a fire-lock is given in *Fig.* 9, where it will be seen that the vestibule between the two stores is provided with two fire-resisting doors fitted with mechanism which makes it impossible for either door to be opened unless the other door is shut and locked.

In conclusion, we give the results of a series of tests conducted on July 5th by the architects, upon one of the floors of the new buildings. The floor area selected for the purpose of the official tests was situated on the ground floor, and measured 19 ft. 6 in. by 12 ft. 6 in. It is carried by one of the main beams 8 in. wide by 6 in. deep, exclusive of the floor slab, which is 3 in. thick. The floor construction, including main and secondary beams and a continuous floor slab, has bent longitudinal reinforcement to provide for continuous-beam action and transverse stirrups to withstand shearing stresses.

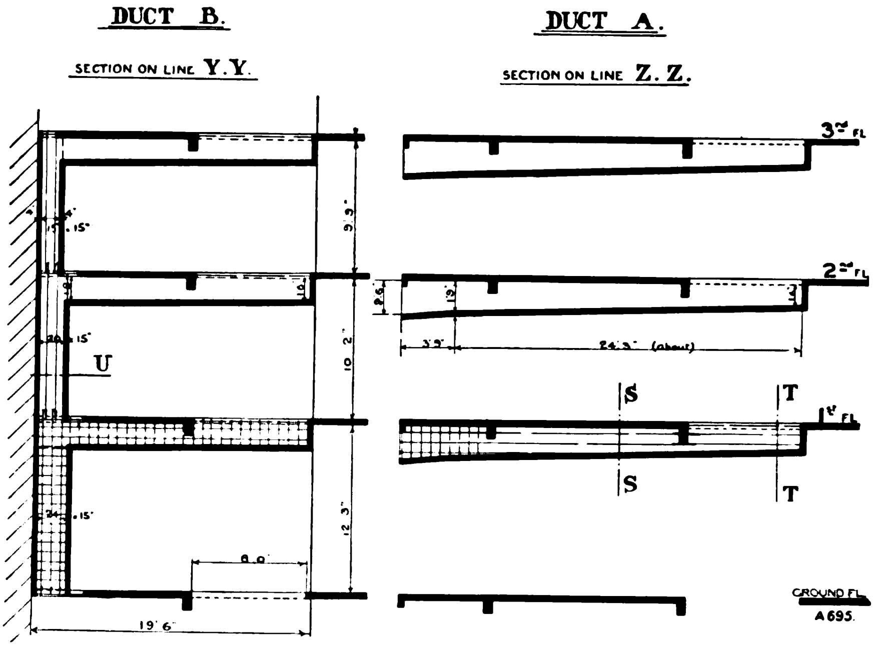


Fig. 5. Vertical Sections showing Ducts.

In compliance with the terms of the specification, the floor area was loaded to the extent of 3¾ cwt. per sq. ft., or 50 per cent. beyond the normal working load. The results of the test were so interesting that we give them in detail as follows:—

LOAD TEST.

For the measurement of deflection three sensitive instruments, giving readings in 500th parts of an inch, were placed beneath the beam, one in the middle of the span and the others at the distance of 6 in. from the supports. In the following table we give the various deflections observed during the process of loading :—

Time.	Load in cwt. per sq. ft.	Deflection of decimals of an inch.		
		Left-hand end.	Middle.	Right-hand end.
12 noon	0·00	0·000	0·000	0·000
—	1·64	0·004	0·036	0·012
1.0 p.m.	2·46*	0·016	0·080	0·024
2.15 p.m.	2·79	0·020	0·096	0·028
2.40 p.m.	3·77	0·040	0·164	0·044
3.40 p.m.	3·77	0·040	0·168	0·044
4.0 p.m.	3·77	0·040	0·168	0·044

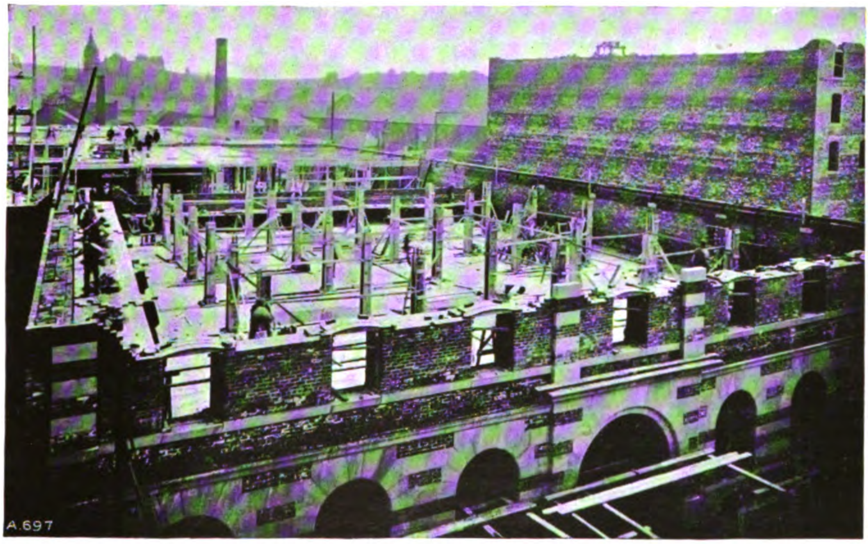
* This load remained unaltered for one hour.

At 4 p.m. unloading was started, and at 9 a.m. on the succeeding morning, when the load had been entirely removed, the deflection registered was scarcely appreciable. By 12 noon of the same day the indicators of the three instruments all pointed to zero.

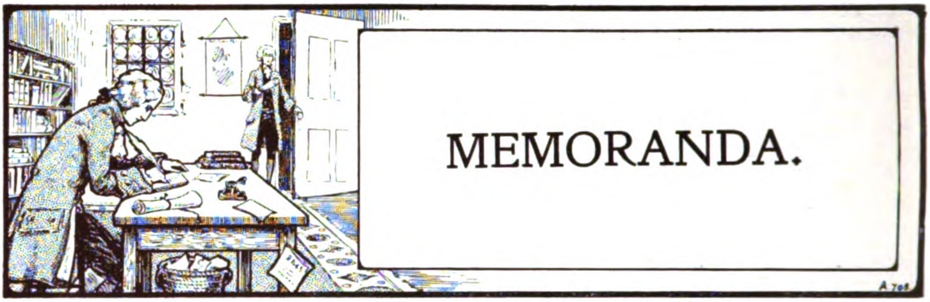
The maximum deflection of 0·168 is equivalent to one 1390th of the span, which compares very favourably with the proportion of one 600th permitted by the terms of the specification.

Other satisfactory points were that no surface cracks were developed in the concrete, and that the perfect elasticity of the construction was proved by the disappearance of deflection on removal of the loading.

The building contractors were Messrs. Thorburn & Son, of Edinburgh, and all details of the reinforced concrete construction were prepared by Mr. L. G. Mouchel, C.E., agent for the Hennebique system, who was represented during the execution of the works by Mr. T. J. Gueritte, of Newcastle-on-Tyne.



The New Reinforced Concrete Warehouse for Messrs. Watson, Dundee, in course of construction.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Questions in the House of Commons regarding the Use and Efficiency of Reinforced Concrete in Public Works.—We have from time to time referred in our editorial pages to the questions and replies bearing upon the use of reinforced concrete under Government Departments, and as we are in receipt of quite a number of enquiries as to the actual wording of the information given by the heads of the various departments in question—namely, H.M. Office of Works, the War Office, and the Admiralty—we think the following short summary of replies given to the questions which were put by Mr. Rowland Whitehead, M.P. (South-East Essex) will meet the case. We need hardly say that we consider the questions and replies speak for themselves, and do not require any further comment on our part :—

THE OFFICE OF WORKS VIEW.

Question.	*Reply of the First Commissioner of Works* (*Mr. Harcourt, M.P.*).
Whether the post office buildings, other than the General Post Office, were being constructed, or were about to be constructed, of reinforced concrete; whether the estimates for any such buildings showed material economy compared with post office buildings erected with ordinary materials, and, if so, what was the extent of the saving, approximately per cubic foot?	*The other buildings being constructed, or about to be constructed, of reinforced concrete are The Manchester Principal Sorting Office, Birmingham Store Building, London Western District Post Office. The approximate savings are 20 per cent.*

THE WAR OFFICE VIEW.

Question.	*Reply of the Secretary of State for War* (*Mr. Haldane, M.P.*).
Whether reinforced concrete had been used by his Department for constructional purposes at Woolwich or elsewhere, and, if so, whether the work had been applied above ground or in foundations; whether it had given satisfaction; whether it had been found economical; whether the War Office had experienced any accidents in the execution of the work; and what was the date of the earliest instance of such work executed for his Department.	*Reinforced concrete has been employed to a considerable extent in construction both at Woolwich Dockyard and at Woolwich Arsenal. This material has been made use of in foundations, in piling and above ground, and is considered to be satisfactory and economical. No accidents have been experienced either during execution or since occupation. The first instance of its use there was in the construction of a storehouse at Woolwich Dockyard, erected between October, 1904, and September, 1905. In addition to the above, reinforced concrete has been employed in the construction of a roof and stairway in Cairo in 1905, and was found economical and satisfactory.*

THE ADMIRALTY VIEW.

Question.	*Reply of the Civil Lord (Mr. George Lambert, M.P.).*
Whether the Admiralty have made use of reinforced concrete in connection with Government works or buildings. Whether the material has been found suitable and economical; whether it has given satisfaction and when first it was used for Admiralty purposes?	*Reinforced concrete is used by the Admiralty in the construction of floors, jetties, etc. Though the prime cost is higher than that of timber, the small cost of maintenance renders it more economical, and there is no reason to anticipate that it will not continue to be satisfactory. It was first used in large works in 1904.*

The Home Office Committee on Wages in the Cement Trade.—The Home Secretary has appointed a Committee to inquire and report what would be the best means of securing, to persons employed in lime and cement works and chalk quarries who are paid by weight or by measurement, the means of ascertaining the correctness of the wages they receive. The Committee is constituted as follows:—Messrs. Ernest F. G. Hatch (chairman), J. N. Bell (of the National Amalgamated Union of Labour), Alfred Brooks (Associated Portland Cement Manufacturers), J. E. Harston (one of His Majesty's Inspectors of Factories) and J. Lloyd Morgan, K.C., M.P. Correspondence may be addressed to the Secretary, Mr. A. Maxwell, of the Home Office.

Dover Harbour.—The great Dover Harbour works are now nearing completion, and the new breakwaters are indeed remarkable examples of the advantageous use of Portland Cement Concrete. No fewer than 63,000 concrete blocks have been required for the main work of the contract, 29,000 being put into the South Breakwater, 18,000 into the East Arm, and 16,000 into the Admiralty Pier Extension. Together, these represent 1,150,000 cube yards, for a total length of 9,154 ft., excluding the east reclamation of 3,910 ft. In addition, nearly 5,000 blocks are laid in forming the stout apron which protects the new works on the outside. The weight of these blocks ranges from 25 tons to 41 tons. All have been made on the spot, the ballast being brought from Sandwich and the Portland cement from the works on the Medway and the Thames, Cornish granite being employed to face the outer blocks. The latter are keyed together with joggles, 12 in. in diameter. There are two joggles at each side of a block, and the keying is effected by ramming into each groove a canvas bag containing Portland cement concrete. The whole of the blocks have been laid from staging by overhead Goliaths, capable of lifting forty tons or more. Blue gum was selected for the staging piles, so that, if accidentally knocked down, they would at once sink, and cause no obstruction in the water.

Concrete in the Rebuilding of San Francisco.—A well-known civil engineer of San Francisco, Mr. W. H. Hall, has compiled a list of the reinforced concrete buildings to be erected in the burned district, and finds that they will number seventy-nine structures. A full list of the buildings was recently published in the San Francisco *Chronicle,* which states that there may be several small structures of the kind, and several which in part only are reinforced concrete, that are not named in this list, but it is believed that it includes all noticeable buildings of the kind. It does not, however, include steel-frame buildings having reinforced concrete parts.

Summarising according to storeys, Mr. Hall finds 4 one, 11 two, 21 three, 8 four, 7 five, 9 six, 8 seven, 7 eight, and 1 ten-storey buildings. Nearly all have basements in addition to the storeys enumerated. Of the number, about thirty-five are finished, or nearly so; about half-a-dozen have very recently been commenced, and the balance are in various stages of progress.

As to the declared uses of these buildings, they are about as varied as could be, but include—14 stores, 13 offices, 10 warehouses, 5 factories, 1 mill, 3 lofts, 2 wholesale stores, 1 wholesale market, 1 store and residence, 7 stores and offices, 4 stores and rooms, 1 store and bank, 1 office and bank, 1 apartment house, 2 rooming-houses, 1 residence, 2 hotels, 1 club, 1 laboratory, 1 sanatorium, 2 power stations.

Reconstruction of Jamaica.—It is said that broad principles have been laid down that in the reconstruction of the buildings in the business portion of Jamaica, steel-frame construction or reinforced concrete alone be used.

The Longest Concrete Arch Span.—The new concrete arch in Fairmount Park, Philadelphia, has a clear span of 233 ft. and a rise of 70 ft. 3 in. The *Engineering Record* (New York) gives some particulars of the arch, which is constructed of two ribs, each 18 ft. wide and 18 ft. in the clear from the bridge axis. Each main arch rib contains about 2,400 cub. yds. of concrete, and was erected on timber and steel false-work. The shrinkage of the false-work during the hot weather, it is said, afforded a desirable means of gradually transferring the load to the arch ring.

Longest Solid Concrete Bridge.—The longest solid concrete bridge in the world is supposed to be that which spans the Hudson River at Sandy Hill, N.Y., U.S.A. The bridge is 1,000 ft. in length, and contains 40,000 concrete blocks joined by means of cement.

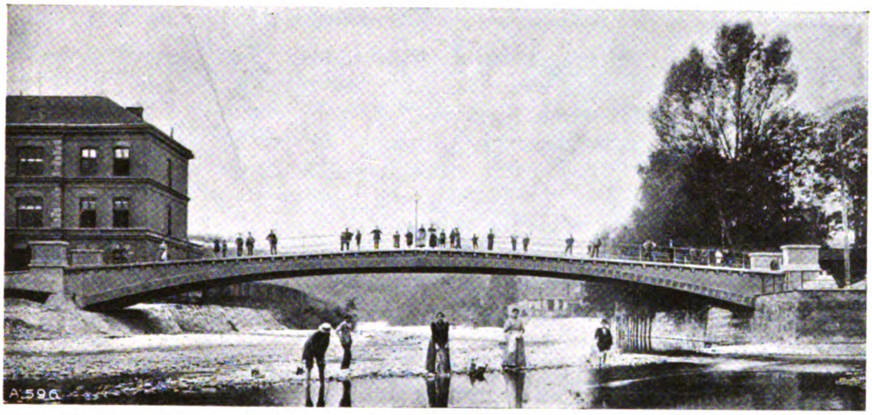
The "Swimming-School" Bridge at Steyr, Austria.—The following is a description of the Swimming-School Bridge at Steyr, of which we present two illustrations. It is an interesting example of reinforced concrete work in Austria, with the additional peculiarity that the bridge has had to withstand several severe floods, reaching well over its haunches.

This bridge, which was constructed in 1898 on the Melan system, crosses the principal arm of the River Steyr, in the town of Steyr. It replaced a timber bridge which had been destroyed by a flood. For this reason no piers could be used. The span was to be 137 ft. 6 in., the width of roadway 19 ft. 8 in., and the choice lay between a steel lattice bridge and an arch. The conditions of the latter were specially difficult, since the high-water level was only 1 ft. 7½ in. below the level of the banks. It was, however, possible to place the abutments 4 ft. 10 in. below high-water level, to raise the roadway on both banks about 3 ft. 3 in., and to give the bridge a rise of about 8 per cent. towards the crown. It was decided to construct the bridge according to Professor T. Melan's design, since the bridge promised to be effective in appearance and to involve no cost of maintenance.

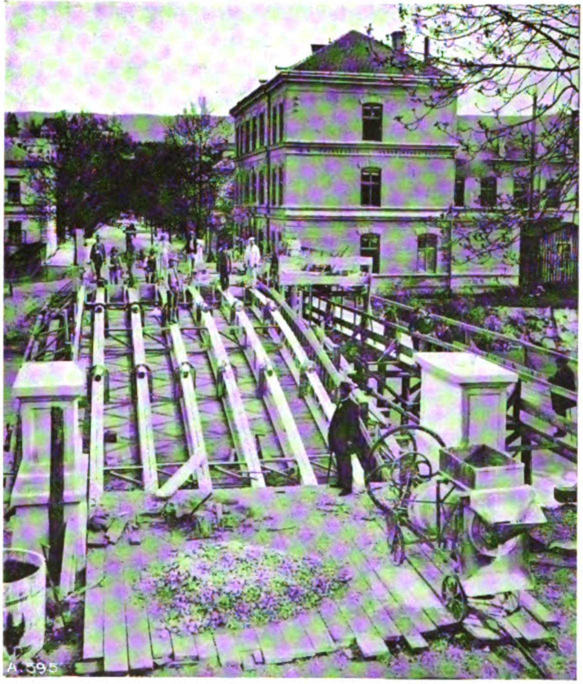
The arch of the bridge has, in accordance with the above requirements, a clear span of 137 ft. 6 in., and a rise of 8 ft. 6 in. The Swimming-School Bridge is therefore apparently the flattest reinforced concrete long span bridge yet constructed. The thickness of the concrete arch is 1 ft. 11½ in. at the crown, 2 ft. 3 in. at the abutments, and increases at the middle of each half-arch to 2 ft. 7 in. Professor Melan constructed the bridge, in accordance with his usual practice, as a three-hinged arch, so that any slight shifting of the abutment piers should involve no danger to the arch.

As reinforcement Professor Melan employed steel lattice-girders, composed each of two angle-irons $\frac{120 \times 120}{15}$ with flat iron rods 10 in. × ½ in. rivetted on in the neighbourhood of the hinges. These girders lie 3 ft. 3 in. apart, and are 1 ft. 7½ in. high at the crown and abutments and 2 ft. 3 in. at the middle of each segment of the arch. They are connected at six places by angle irons placed transversely. The iron arches were not brought to the site complete, but were delivered in six sections.

With respect to the hinges, these were designed according to Köpke's method, concrete blocks being placed in the crown and abutments, with cylindrical bearing surfaces of slightly differing curvature. These blocks are 1 ft. 7½ in. wide, and were prepared beforehand from a 1 : 4 mixture. Between each block and the next iron arch was a space of 10 in., which was filled in by ramming, asbestos being first placed in the hinge joints. The filling and ramming of the concrete was begun simultaneously at the crown and at the abutments, special precautions being observed. The concrete used was 1 part cement, 2 parts sand, and 4 parts broken stone.



It is a particularly advantageous characteristic of the Melan system that the iron arches can be used to carry the centering, this being suspended from the arches. This fact makes it possible to construct Melan bridges where independent centering cannot be erected. Another consequence of this peculiarity is that the centering itself can be lighter than usual, and that the iron arches can also carry a part of the dead weight of the arch, so that the arch itself is relieved.



THE "SWIMMING SCHOOL" BRIDGE AT STEYR.

The centering rested on piles about 19 ft. 8 in. apart. The steel arches were then put in place, and then the wooden planks resting on the piling were attached to the arches by iron stirrups. In this way the arches were made to carry about one-half of the whole weight on the planking. The stress thus produced in the angle-irons of the arch amounted to about 8,500 lb. per sq. in.

The abutment piers were of concrete blocks, 39 ft. 4 in. long, and going down to a depth of 11 ft. 5 in.

The bridge not only passed its loading tests well, but is now, nine years after completion, standing uninjured, after having withstood several floods of exceptional severity.

Stakeford Bridge, Northumberland.—This bridge has a total length of 264 ft. between abutments, and comprises six girder spans 44 ft. 4 in., from centre to centre of the piers, by 20 ft. 4 in. wide. The piers are formed by driving reinforced concrete piles down to solid rock. According to contract conditions the bridge will be tested by a dead load of 1 cwt. per sq. ft. and the moving load of a 30-ton steam roller. It is stated that the adoption of reinforced concrete has resulted in a saving of £5,000 to the ratepayers, the contract price being £7,000 as compared with £12,000, the estimated cost of a steel bridge. The system of reinforced construction was that of Messrs. Hennebique.

Concrete Paving Materials.—It may be of interest to some of our readers who hold office with municipalities, that suggestions are being brought to the notice of the Belfast Corporation as to the inadvisability of any further paving being executed with so-called " kidney " paving stones, which were all too frequently used by the Belfast rioters as weapons.

We should have thought, ourselves, that in a city the size of Belfast, concrete covered with asphalte should be used, not only from the point of view of rioting, but from the important aspect of hygiene.

A new Reinforced Concrete Pavement.—A new pavement in Paris, described in *Good Roads Magazine*, is built of reinforced concrete with steel framework and concrete filling. The experimental section has been laid in front of the Conservatory of Arts on Rue St. Martin.

The metal part of the pavement consists of a plate of perforated steel, with strong spikes or bolts of steel running through it between the perforations. Each metal section is said to resemble a steel harrow, except that the spikes project equally on each side, and are square and blunt on the ends. The metal sections are laid on a concrete base, after which a specially prepared concrete in a soft condition is shovelled upon them and rammed down, making a solid mass level with the tips of the prongs of steel. The steel points thus exposed are so close together that the horse's shoes and the wheels of the vehicle will rest partly on them and partly on the concrete.

It is claimed that this new pavement will be more durable than asphalt, wood-block or any other pavement designed up to this time. It is also thought that as the concrete will wear faster than the steel points it will make the surface sufficiently rough to afford good foothold for horses, and at the same time not so rough that it will interfere with the tractive resistance or the power required to draw loads over it.

A Reinforced Concrete Reservoir Cover.—The new covered service reservoir at Shedfield, forming part of the Soberton scheme of the Gosport Waterworks Co., built entirely of reinforced concrete on the Hennebique system, has recently been tested under the direction of the designer, Mr. E. T. Hildred, M.Inst.C.E., Engineer to the Waterworks Co.

The reservoir comprises vertical walls 6 in. thick at the bottom and 4 in. thick at the top, and a continuous floor slab, 7 in. thick, distributing the load at the rate of 2 tons per sq. ft. over the ground. The walls are stiffened by counterforts at frequent intervals along the exterior, and a partition wall divides the interior into two equal portions. The roof is supported by the outer and partition walls, and by columns, 10 in. sq., built up from the floor slab and spaced apart 16 ft. 8 in. longitudinally and 16 ft. transversely. These columns support 8 in. by 16 in. main beams, and 7 in. by 12 in. secondary beams, each bay of 16 ft. 8 in. by 16 ft. being subdivided into three panels by two additional secondary beams. The thickness of the roof slab is 4 in. throughout. Its capacity is stated to be 2,000,000 gals.

For the official tests the engineer selected one complete bay between four columns, being the second bay from the north and the third bay from the east side, and one main beam in the third row from the north end and the third span from the west side.

The subjoined tables give particulars of the loading and the deflections observed during and after the tests.

TABLE I.—TESTS OF ROOF BAY. (SHEDFIELD RESERVOIR.)

Area of bay 16 ft. 8 in. × 16 ft. 0 in. = 266.66 sq. ft. Recording instruments A & B placed beneath the middle of the two intermediate secondary beams dividing the bay into three panels.

Superload.		Deflection.			
		Decimals of an inch.		Proportion of span.	
Depth of sand weighing 96 lb. per cub. ft.	Cwts. per sq. ft. of roof bay.	Instrument A.	Instrument B.	Instrument A.	Instrument B.
9 in.	0.64	0.032	0.024	$\frac{1}{6250}$	$\frac{1}{8333}$
18 in.	1.28	0.048	0.048	$\frac{1}{4166}$	$\frac{1}{4166}$
27 in.	1.92	0.072	0.072	$\frac{1}{2777}$	$\frac{1}{2777}$
36 in.	2.57	0.112	0 112	$\frac{1}{1784}$	$\frac{1}{1784}$
49 in.	3.50	0.192	0.184	$\frac{1}{1040}$	$\frac{1}{1087}$
39 in.	2.75	0.160	0.168	$\frac{1}{1250}$	$\frac{1}{1196}$

TABLE II.—TEST OF MAIN BEAM. (SHEDFIELD RESERVOIR.)

Beam 8 in. wide by 16 in. deep (exclusive of roof slab). Span of beam 16 ft. 0 in. Area of load 16 ft. 8 in. × 16 ft. 0 in. = 266.66 sq. ft. One recording instrument placed beneath middle of beam.

Superload.		Deflection.		
Depth of sand weighing 96 lb. per cub. ft.	Weight per sq. ft. of area loaded in cwt.	Weight on the beam in tons.	Decimals of an inch.	Proportion of span.
24 in.	1.75	23.33	0.072	$\frac{1}{2666}$
49 in.	3.50	46.66	0.124	$\frac{1}{1548}$
39 in.	2.75	36 66	0.108	$\frac{1}{1777}$

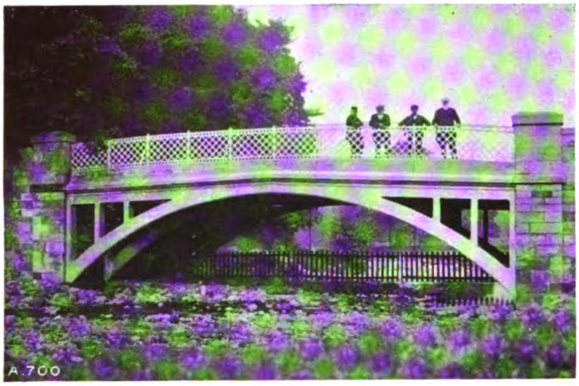
"Bonna" Pipes.—We are pleased to learn that in connection with the Norwich contract for reinforced concrete water mains, which are to be constructed on the Bonna System by the Columbian Fireproofing Co., Ltd., the well-known inventor, Mr. Bonna, has been making a protracted stay in this country in order to personally assist in the necessary arrangements in the work and give the benefit of his great experience in this form of pipe construction. It is always pleasant to see an inventor painstaking. The reverse is too frequently the case.

Lilburn and Lucker Bridges, Northumberland.—On page 426 of our previous volume (issue No. 6) reference was made and drawings shown of the Lilburn and Lucker Bridges, Northumberland. These have now been completed, and were tested on September 25th, and we now present two photographs illustrating them.

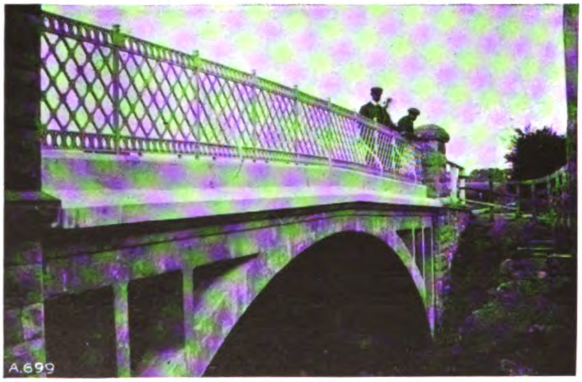
Regarding the test, a 17-ton steam-roller was first passed across the bridge, which gave a deflection of 37-1000ths of an inch. The roller was next brought to rest at the centre of the bridge, the two hind wheels being concentrated upon the centre rib, which gave a deflection of 40-1000ths of an inch, but when the roller was removed there was no permanent set whatever. The span of each bridge is 40 ft., and the permissible deflection at 1-500th of the span will be seen to be 800-1000ths, whereas the actual tests were 37-1000ths and 40-1000ths only.

Both bridges were tested with a roller of the same weight, and the deflection obtained was exactly the same in each instance.

These bridges were tested in the presence of Mr. J. A. Bean, County Surveyor, Northumberland; Mr. A. G. Drury, Inspector of the Local Government Board; and Mr. Harry W. Taylor, A.M.I.C.E., Engineer to the British Concrete Steel Co., of Newcastle-on-Tyne, who constructed the bridges.



LILBURN BRIDGE, NORTHUMBERLAND.



LUCKER BRIDGE, NORTHUMBERLAND
(constructed in reinforced concrete).

Concrete Mining Town.—The American Smelting and Refining Co. has started a new town near Trinidad, and contracted for the erection of 80 houses, to cost £100,000 (American cost). Every building in the town will be of concrete. The only wood to be used will be on the roofs and the inside fittings.

Concrete and Steel at Fires.—On the occasion of the meeting of the National Fire Brigade Union at Bradford on October 11th, a paper was read by one of the vice-presidents, Mr. Edwin O. Sachs, F.R.S.Ed., on the subject of Concrete and Steel at Fires. The paper dealt with steel-frame construction having concrete filling and with reinforced concrete, and the summary of Mr. Sachs' advice to fire chiefs when called in to approve of plans for buildings was:—

1.—See that all your steel is protected, no matter where it is.

2.—See that it is protected with good Portland cement concrete of proper aggregate.

3.—See that all external angles on the concrete coverings are rounded.

The Earl of Londesborough presided at the reading of the paper, which was illustrated by lantern slides arranged by Mr. Ellis Marsland, hon. sec. to the British Fire Prevention Committee. On the following day the fire chiefs were shown over the Saltaire Mills of Messrs. Titus Salt, where some extensive floors (on the Hennebique system) of reinforced concrete were in course of construction.

Lecture on Reinforced Concrete.—A public lecture of considerable interest was given at the Engineering Exhibition, at Olympia, by Professor Henry Adams, M.Inst.C.E., on the subject of Reinforced Concrete, Mr. H. D. Searles-Wood, F.R.I.B.A., presiding. The paper was well illustrated by lantern slides and there was a good attendance.

It is characteristic of the increasing interest in reinforced concrete that this subject should be dealt with in a public lecture at a general engineering exhibition.

A Useful Code of Instructions on Reinforced Concrete Jobs.— In a previous issue we mentioned under *Memoranda* a small handbook of instructions issued by the Trussed Concrete Steel Co., of Detroit, U.S.A., regarding materials and workmanship, for the superintendents and inspectors of their system of reinforced concrete, and we indicated that these instructions could scarcely be improved upon.

The fact that the few failures in reinforced concrete which have occurred are due mostly to carelessness or laxity on the part of the clerk-of-works or foremen controlling the workmen makes a handbook of this kind almost an essential, and certainly a most useful aid to memory, easily grasped, and of a shape and size that allows of its constant carriage as a reference book without inconvenience.

It does great credit to the management of the system in question that based upon their recent experiences such a handbook should have been issued, and it speaks for their efforts to have careful work done where their special bars are applied.

We think this is a case where other specialists or purveyors of proprietary systems, even if they have not encountered the same trouble, would do well to follow the lead given, and we consider that all encouragement should be accorded to the publication of such handbooks of instructions.

We are reproducing part of the handbook on another page, as we hold it one of the most interesting summaries of its kind, and meriting a place under our heading of "Rules and Regulations." Of course, having been prepared at Detroit, U.S.A., the text is not always entirely applicable to Great Britain, and the chapters on Concreting at Night, Concreting in Freezing Weather, Reinforced Concrete Joist and "Tile" Construction, have been omitted as not generally applicable to this country. But as a whole the instructions merit memorising.

American National Cement Users Association.—We understand that the Fourth Convention of the National Association of Cement Users will be held at Buffalo, N.Y., January 20th to 25th, 1908. The old 65th Regiment Armoury has been engaged for the Exhibition, and it is probable also that the Convention will be held in this building. The indications are that this Convention will surpass the Chicago Convention of 1907.

The Association of Engineers-in-Charge and Cement Manufacture. — MR. ALF. E. PENN, Chairman of the Educational Committee of the Association of Engineers-in-Charge (which has a membership of some 270, with Mr. W. T. Hatch, M.Inst.C.E., as President), sends us the particulars and comments on an interesting visit of his Society to the Northfleet works of the Associated Portland Cement Manufacturers (1900), Ltd. Mr. Penn says:—

"Truly a more interesting and instructive visit could not have been organised for the members of the Association than to these works, seeing that each member must necessarily from day to day be more or less intimately associated with this ever-increasing important engineering commodity. Much information of a practical character was imparted to the visitors by the guides, and all were exceedingly well pleased with the unceasing efforts put forward by the management to ensure that nothing was left unsaid that might ensure a better understanding resulting from this visit in respect to cement manufacturers and cement users. It is scarcely necessary to follow throughout the various operations the chalk and clay passed through which the visitors were brought in contact with in the production of Portland cement, but suffice it to say that each part was scrutinised with the evident intent to acquire all the practical knowledge obtainable, while much interest was evinced in the very modern and costly methods adopted to ensure the most satisfactory product being manufactured, for no pains or expense seemed to have been spared to bring about this result, and it was still evident that the works management were pushing forward schemes even now for further improvements in cement manufacture.

"One would have thought that all had been said which could be about cement when the tour of the works had been made, but a further store of information had been saved by one of the directors, Mr. E. W. Brooks, for the conclusion, by way of a humorous and interesting lecturette extemporaneously given which proved the climax of the afternoon. Professor Henry Adams, on behalf of the Association, thanked Mr. Brooks and his co-directors for their hospitality."

H. M. Gunwharf, Portsmouth.—The immense storehouse which was destroyed by fire last year is to be reconstructed in reinforced concrete on the Hennebique system, the contractors being Robert H. B. Neal, Ltd., of Plymouth.

Recent Contracts.—Among the important works recently contracted for by the Stuart Granolithic Co., Ltd., are a new Post Office at Maldon; the reconstruction of floors at the East London Hospital, Shadwell; the East Ham Hospital; two Schools in Yorkshire; Queen Victoria Memorial Schools, Dunblane; new Factories for Reckitts, at Hull; new Factories at Blackfriars; the new Library building at St. Andrews University; a new Hospital at Plymouth; and several other mills, factories, schools and mansions.

Among the more interesting works recently contracted for in which the Patent Indented Steel Bars are to be used, we note in the first place the Stadium for the Olympic Games at the Franco-British Exhibition, for which the contractors are the Empire Stone Co., and also the new offices for the Royal Insurance Co., in Piccadilly, where the same contractors are being employed.

Besides this, mention should be made of the Albert Mills, near Manchester, of a retaining wall in Piccadilly, of a storage tank at Saltley, near Birmingham, for the Corporation of Birmingham, and a water tower 110 ft. high for the Great Grimsby Waterworks.

Among the works upon which the Trussed Concrete Steel Co.'s system has been used, or is being employed in England, we understand the following can be named :—An Extension of Swanscombe Pier; an Office Block for H.M. Land Commission in Dublin; Coal Hoppers for the Blackburn Gas Co.; Offices in Erith, Leeds, and Birmingham; Store Building in the Forth Defences; and the new Telegraph Stores at Birmingham for H.M. Office of Works.

In our Colonies we are informed the list includes the floors of the Bank of Africa at Capetown, some Beams for the Crown Agents for the Colonies at Sierra Leone, an Office Block in New Zealand, and the floors of the new Government Buildings in Rangoon.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

THE NEW HARBOUR AT TANGIER.

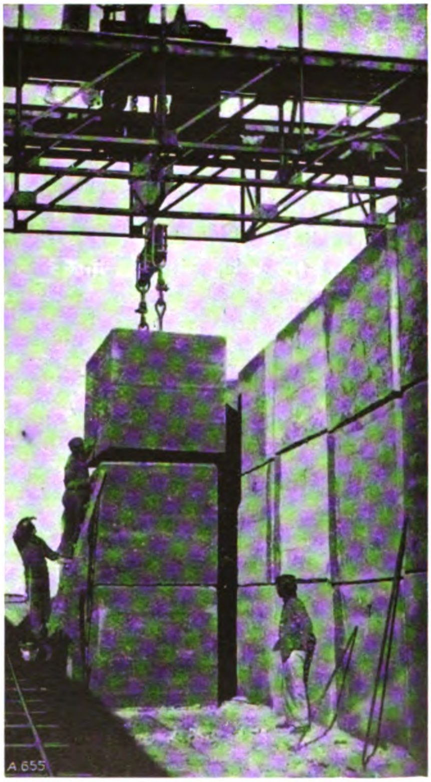
WITH the construction of a port at Casa Blanca by the French, as the direct cause of the serious trouble existing in Morocco, interest is increased in a similar work which is being carried out by the Germans at Tangier.

A contract for the construction of a new port at Tangier was awarded to a German "political" company in February, 1906, for £76,800 which amount was soon increased to £113,800 by the addition of £37,000 for two storehouses.

The company receiving the award is stated to have sublet the contract to the Philip Holtzmann Construction Co., of Germany, at a figure which, it is understood, was about 2,000,000 pesetas, or two-thirds of the original contract price. Work was begun as soon as machinery could be withdrawn by the company from Spanish waters. The contract calls for completion in three years, or February, 1909, and most of the work is of concrete, concrete blocks as illustrated being almost entirely used for the mole.

Quite interesting is the fact that the new mole is built upon the ruins of the one constructed by the English, and blown up by them at their evacuation of Tangier in the seventeenth century. It speaks well for the masonry of the period that three hundred years later it is still in a condition to support the massive new mole, although it has been entirely submerged all that time. All that was necessary to do to prepare it for receiving the immense weight to be placed upon it was to have the surface levelled by the addition of stone, over which was poured a grouting of cement and finely broken rock.

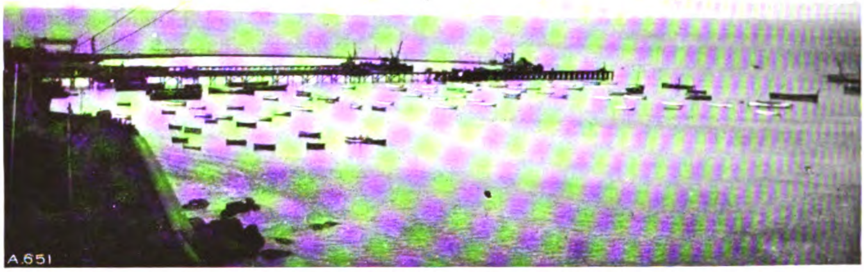
Details of the construction are very difficult to secure, inasmuch as the works are closely guarded, and the photograph showing the blocks in the drying yard is believed to be the only one ever taken within the confines of the works. Most of the points in the construction can, however, be gathered from the photographs, which were taken upon a day when work was progressing in the ordinary manner, and



TANGIER HARBOUR.
Piling the Concrete Blocks in the Drying Yard.

we publish the illustrations as being of topical rather than technical interest.

We are indebted for the foregoing data and photographs to Mr. George E. Holt, of Tangier, Morocco.



TANGIER HARBOUR.
Showing present wooden pier and the unfinished new one.

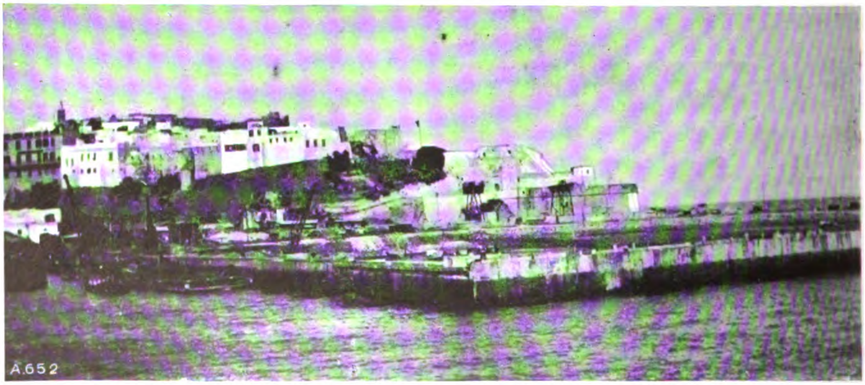
A VILLAGE HALL CONSTRUCTED IN CONCRETE.

AN interesting example of a concrete block building has recently been erected in the shape of a Village Hall in the village of St. Petroc Minor, Cornwall.

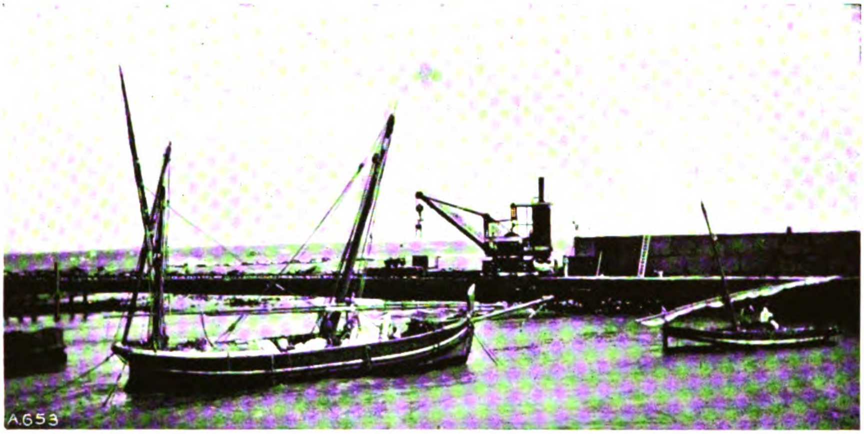
The building consists of a hall 50 ft. long by 24 ft. wide, with a wing 16 ft. by 13½ ft. at right angles to the main building and under the same roof, constructed as a caretaker's house, the whole thus forming the letter L.

It is built of concrete blocks, cast on the site, each block measuring 32 in. long, 9 in. high, and 10 in. thick, with a cavity in the centre to render the wall damp proof. The blocks were composed of 1 part J. B. White Bros'. cement (manufactured by the Associated Portland Cement Manufacturers, Ltd.), 4 parts river gravel and 1 part river sand. A "Pioneer" machine, by the Concrete Machinery Co., Ltd., of Liverpool, was used for making the blocks.

The caretaker's house has a stepped gable, with a niche in the centre containing an image of the patron saint, St. Petroc. The windows are divided into two or more lights by wooden mullions,

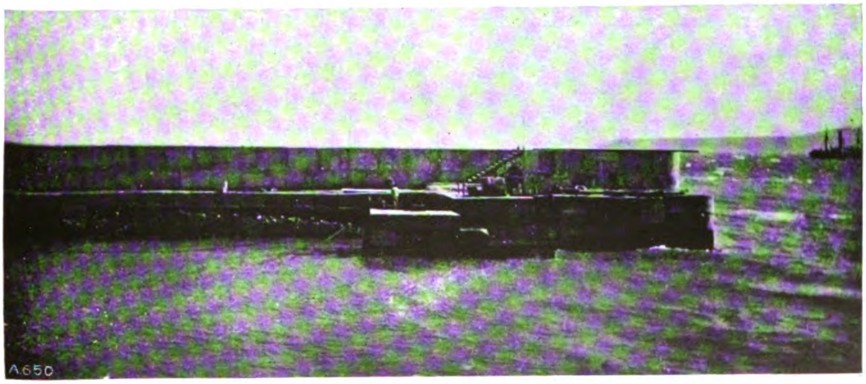


View of the works from the end of the present mole, showing area to be filled.

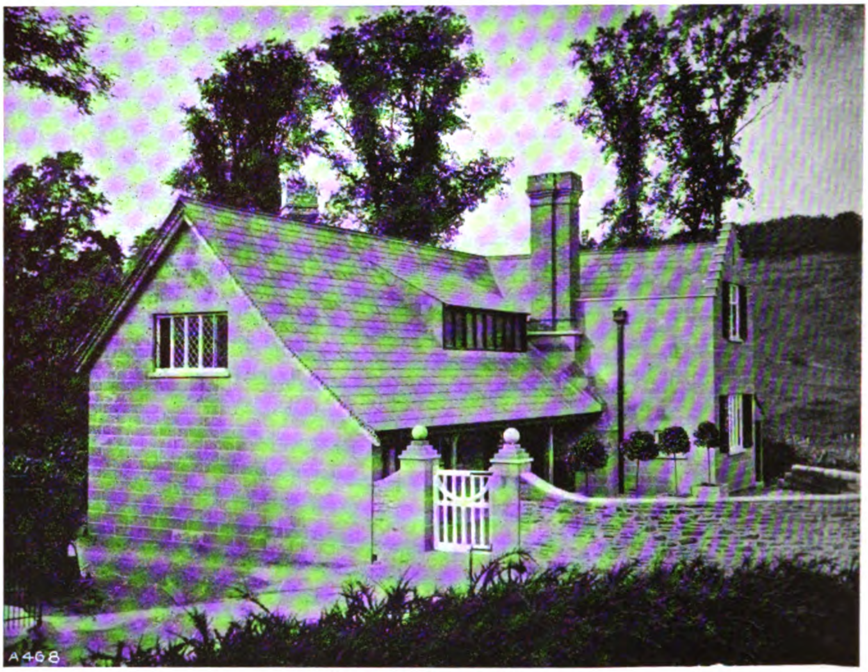


TANGIER HARBOUR.
The new mole, showing crane for placing concrete blocks

Showing dredgers at work



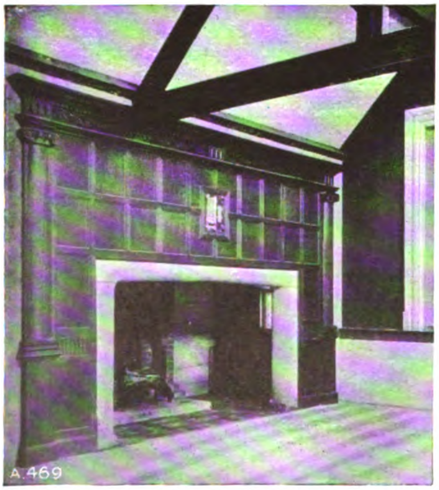
The head of the new concrete mole.



A CONCRETE VILLAGE HALL.

and fitted with leaded glass. The outside shutters are painted a strong green, which looks well on the grey of the concrete walls against which they fold back.

The interior of the hall is divided into two parts, the hall proper measuring 33½ ft. by 17½ ft. and a stage by 10 by 17½ ft. The opening of the proscenium is 10 by 10 ft. At the other end of the hall is a gallery with panelled front, supported on Doric columns. But the main architectural feature of the hall is its chimney place, measuring 13½ ft. by 5 ft. The roof of the hall is open to the ridge, and is plastered on the rafters, showing the purlins and ridge piece supported by kingpost trusses. The hall is lighted by a long dormer window in the roof, a five-light mullioned window over the gallery, and a small window looking on to the verandah.



THE CONCRETE CHIMNEY PLACE.

The lintels and constructional girders are, by the bye, of solid concrete blocks, reinforced, where necessary, by steel rails. The floor is paved with wood blocks, laid in pitch on concrete.

A feature of the work lies in the fact that it has been designed and constructed under the supervision of amateurs, the donor, Mr. Athelstan Riley, having officiated as architect, while Mr. David

Williams, churchwarden of Little Petherick, superintended its construction as clerk of works.

Under these conditions the cost of this concrete building worked out at something under £700, or about 6¼d. per cubic ft., which does great credit to all concerned.

REINFORCED CONCRETE AND CONCRETE BLOCK DYEING AND CLEANING WORKS.

The dyeing and French cleaning department recently added to the establishment of the Monarch Laundry Co., Ltd., at the junction of Monarch Street and Donegal Road, Belfast, is interesting as embodying the first building of its kind hitherto erected in our islands. The original portion of the works, devoted to the purposes of a steam laundry, is a brick building of eight bays, of which seven are covered by saw-tooth or Yorkshire roofs, and is separated from the dyeing and cleaning works by a yard with a gateway for vans opening on Monarch Street.

Fig. 1 is a plan of the new building, which has the total length of 167 ft. and the width of 41 ft. 6 ins., the length of the Donegal Road façade being 152 ft. Articles to be cleaned and dyed are delivered from the yard through doors shown on the plan, passing from the Dry Cleaning Room or the Dye House, as the case may be, to the Finishing Room, near the other end of the buildng, where are situated the offices of the company.

As the intention is that the building will eventually be increased in height by two additional storeys, all the loads, except those of the outer walls, are transmitted through 37 reinforced concrete columns, arranged as shown in the plan, the bases of these columns being proportioned so as to limit the load upon the soil to 1 cwt. per sq. ft. The wall and interior columns are disposed in four rows connected longitudinally and transversely at roof level by main and secondary beams and wall lintels, making a complete skeleton frame, which is further consolidated by the continuous roof slab, pierced at one place only for the rectangular skylight opening over the Dry Cleaning Room.

Fig. 2 is a plan of the roof construction viewed from below, showing the dimensions and arrangement of the columns and beams.

Between and outside the columns the walls have been built up of rock-faced hollow concrete blocks, and the same construction is carried above the upper surface of the roof to form a parapet 3 ft. high.

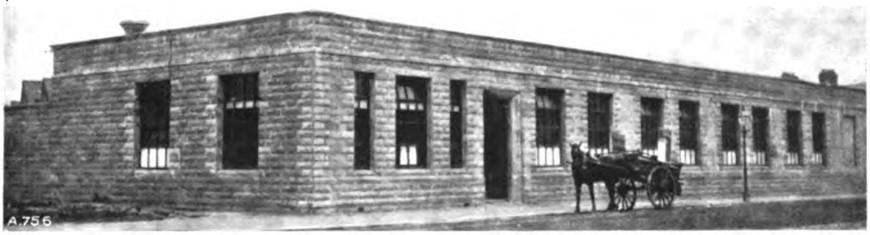
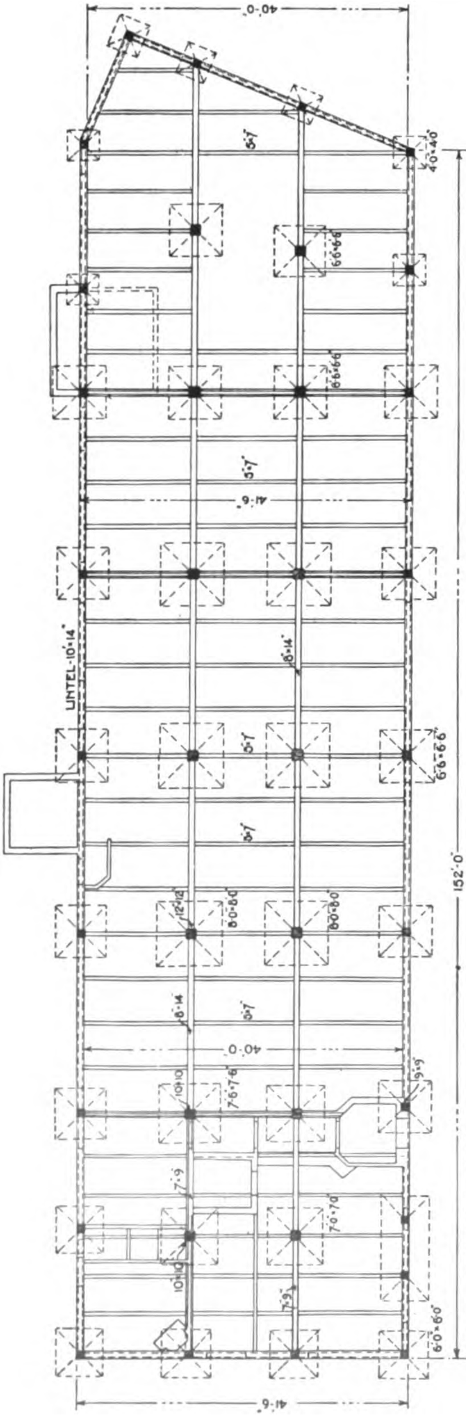


Fig. 3. Concrete Block Exterior of the Monarch Laundry Co.'s New Premises, Belfast.

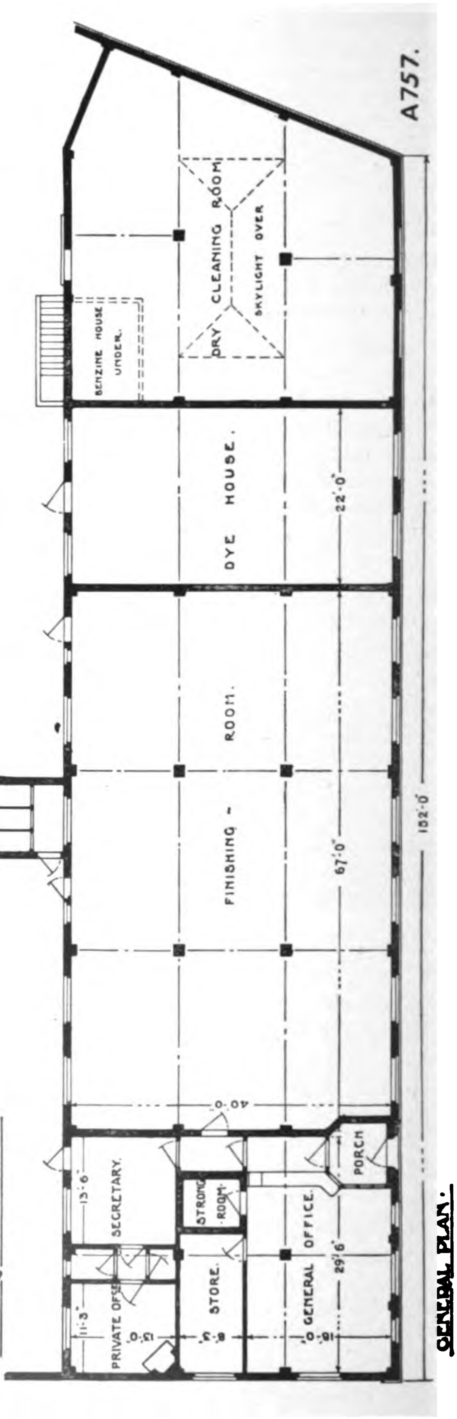
The roof was designed to carry a superload of one cwt. per sq. ft., and consequently, is available for business purposes if occasion should arise, and will constitute the first floor when the time comes for the building to be extended upwards.

Fig. 3 is reproduced from a photograph of the finished structure, which was built by Messrs. J. and R. Thompson, Mr. Jackson Smyth, the architect acting for the proprietors.

All the reinforced concrete work is on the Hennebique system.



CONSTRUCTIONAL PLAN.



GENERAL PLAN.

Figs. 1 & 2. The Reinforced Concrete Building of the Monarch Laundry Co., Ltd., Belfast, faced with Concrete Blocks.

REINFORCED CONCRETE SEWERS.

We have received from Mr. Watkin Hall, A.M.I.C.E., Surveyor to the Urban District Council of Great Crosby, some interesting photographs and particulars of the new sewerage scheme now being carried out in that town.

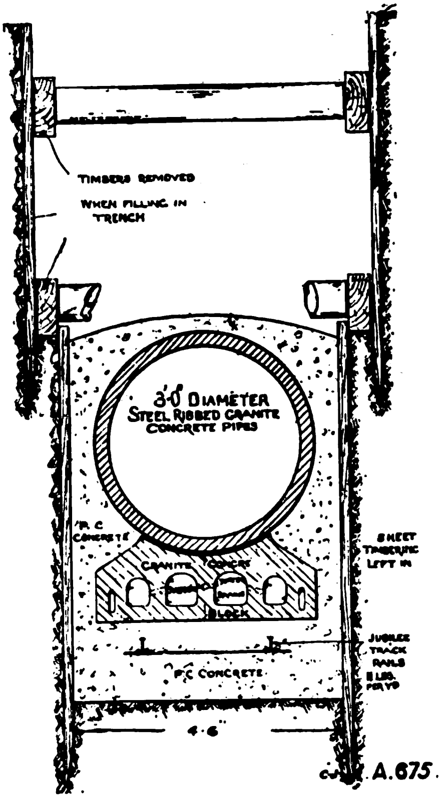
Owing to the unstable and waterlogged condition of the subsoil it was necessary to exercise the very greatest care in the construction of this sewer, as it is stated the ground could scarcely be worse, being composed largely of sand and peat, waterlogged at a depth of 2 ft. to 3 ft. below the surface.

The Council, after careful consideration, decided that the "Aqueduct" Granite-Concrete blocks, manufactured by Messrs. John Ellis & Sons, Ltd., of Leicester, were the only type of base that appeared likely to give the necessary solidity in the running subsoil.

The photographs and drawings clearly show the details of these, and the means adopted to meet the difficulties of such unstable ground. The layer of concrete in the floor is reinforced by ordinary Jubilee track rails, with steel sleepers, and upon this bed the "Aqueduct" blocks are laid, and are at once ready for the bricklayers to proceed, a satisfactory and sound invert being secured once the blocks are fixed. The saving in time with this method is a great consideration, as four men with a crane are able to lay 80 to 100 lineal yds. per day if the excavators are ready for them.

The Council have now completed the foreshore work, which has a length of some 120 lineal yds. This portion of the sewer consists of 3 ft. diameter steel-ribbed granite-concrete pipes, and is joined up to an egg-shaped brick sewer measuring 4 ft. by 2 ft. for 793 lineal yds., and 3 ft. 9 in. by 2 ft. 6 in. for the rest of its length. The total length of the sewer will be over 2 miles.

Mr. Hall maintains that these reinforced concrete specialities have proved eminently superior to the ordinary stoneware goods, and recommends it as an admirable material for all new sewerage schemes.



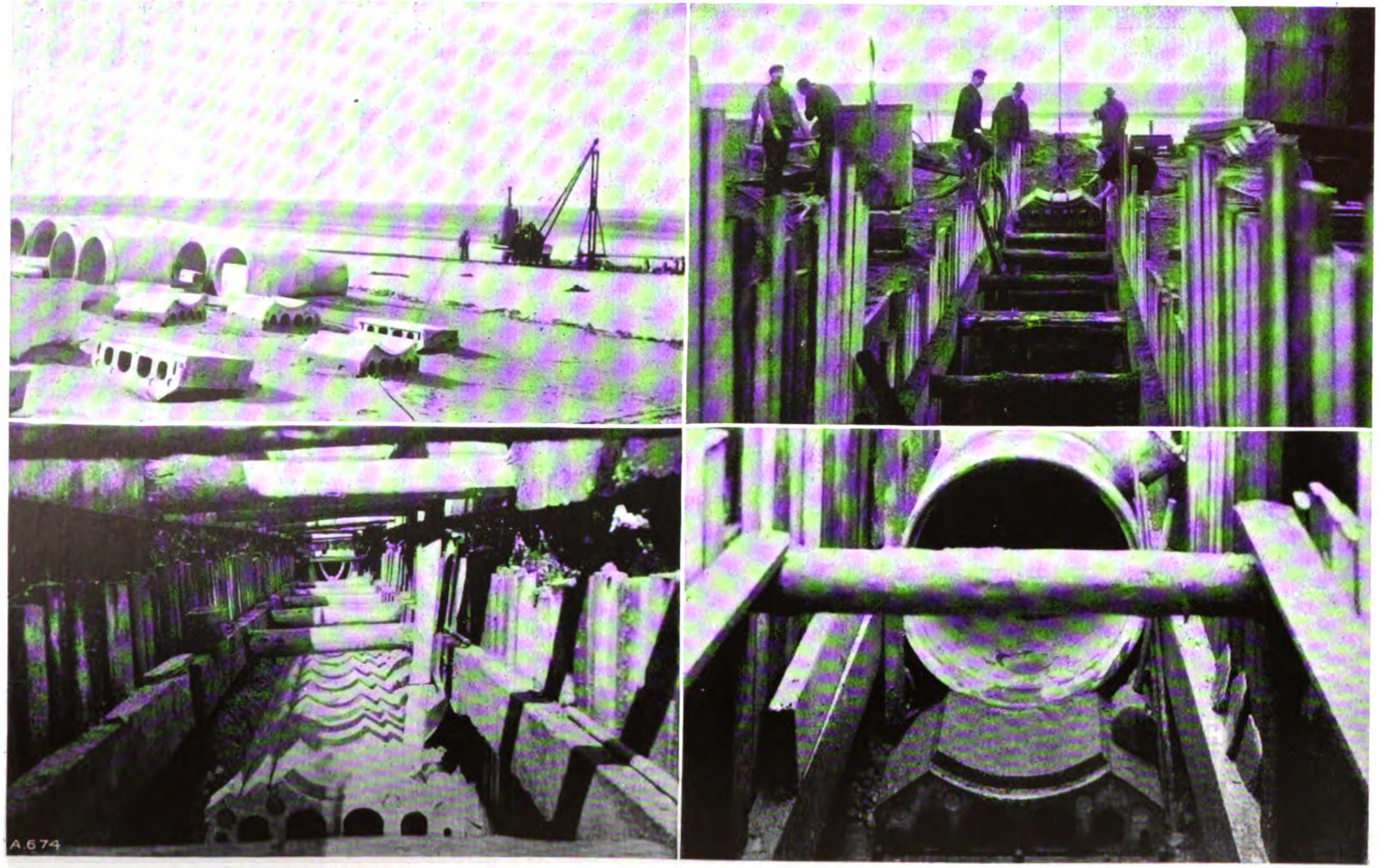
Section through Reinforced Concrete Sewer at Great Crosby.

NEW BUILDINGS IN THE UNITED STATES ON THE "MUSHROOM" REINFORCED CONCRETE SYSTEM.

We are reproducing some illustrations of buildings in the United States, on a system of reinforced concrete construction that is somewhat novel, and is generally known as the "Mushroom" system.

The essential feature of this system of construction is the formation of a so-called mushroom at the top of each column, by extending its reinforcing rods, laterally, some 4 ft. or more out into the slab in a radial direction, and supporting on these ring rods, which, in turn, carry the lighter reinforcement for the slab construction.

The top of the column is enlarged, forming a neat capital, which assists in taking



The New Reinforced Concrete Sewers at Great Crosby in course of Construction.

the additional stress which comes upon it in supporting the entire slab at this point. The slab reinforcement consists of parallel rods of small diameter, running between adjacent mushrooms, both at right angles and diagonally, and of a width equal to the diameter of the mushrooms. The slab rods are strung over the mushroom frames and are given the necessary sag to bring them near the bottom of the slab between the columns. They are further wired together at their intersections to form a netting, and to hold them securely in place. In this manner, the steel reinforcement is well distributed through the slab, which is thereby made continuous in all directions.

Fig. 1 shows the reinforcement of a column in the Hamm Brewery Co.'s building in St. Paul, Minn., with the footing in place ready for the concrete.

The working load on the column is calculated at 1,000 tons, the diameter of hoop being 27 in., the working pressure on concrete developed by the hoops 2,500 lb. per sq. in., and the vertical pressure figured on steel 12,000 per sq. in. The largest panel in this building is 22 ft. 10 in. by 26 ft. exactly, the others being a trifle smaller. The working load is about 900 lb. per sq. ft., and it is stated that the saving in cost over structural steel and terra-cotta is about £9,000 (American cost). The dimensions of the building are 80 ft. by 120 ft.

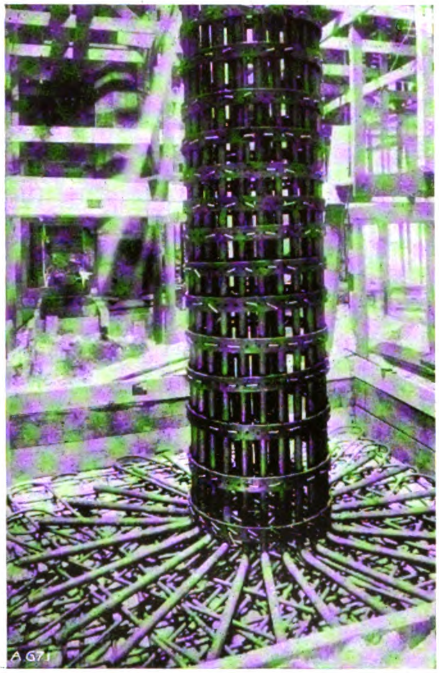


Fig. 1. Reinforcement of Column for the Hamm Brewery Co., St. Paul, U.S.A.

Fig. 2 represents the floor of the Hoffman building in Milwaukee, Wis., and gives a very good idea of the mushroom

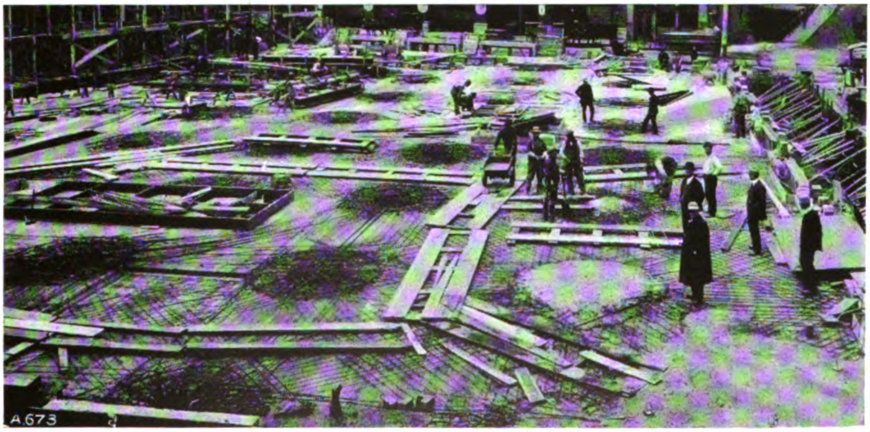


Fig. 2. Reinforced Concrete Floor of the Hoffmann Building, Milwaukee.

heads. A test load on this floor of 1,000 lb. per ft., consisting of gravel in bulk, held in by a wall of gravel in sacks, resulted in a deflection of $\frac{7}{16}$ of an in.

Fig. 3 is the exterior of the Lindeke-Warner building, St. Paul, Minn., which was erected at the rate of about one storey in every ten days. This building, which is one of the largest reinforced concrete structures in the country, consists of seven floors and a basement, has a floor area of over 38,000 sq. ft., and is designed to carry a load of 750 lb. per sq. ft. of floor area.

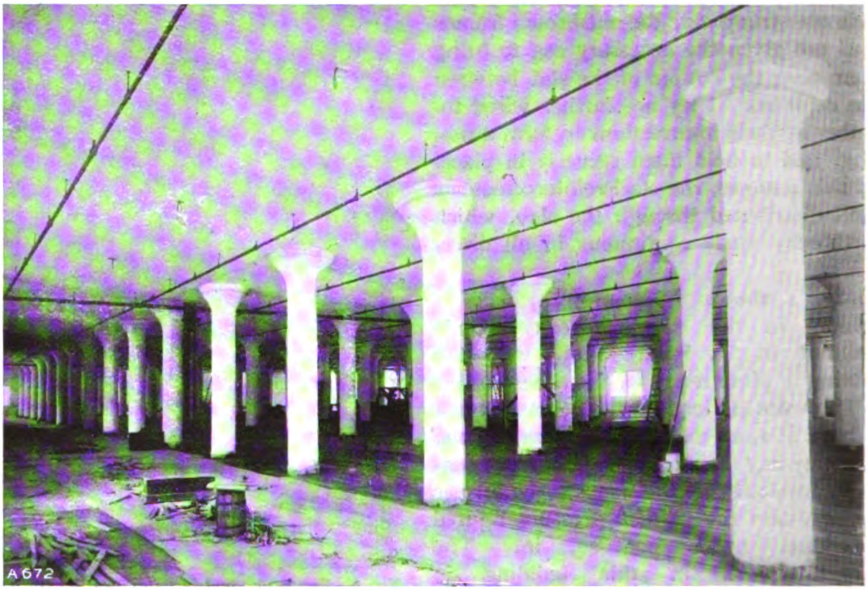
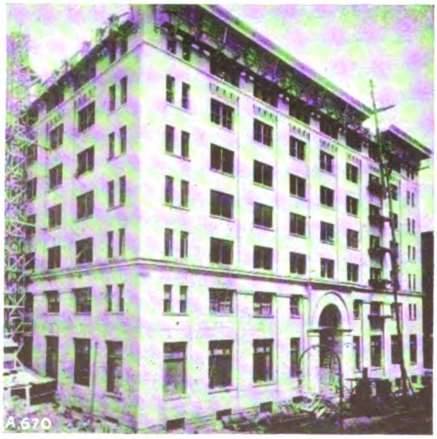


FIG. 3. INTERIOR OF LINDEKE-WARNER BUILDING, ST. PAUL.
Showing Reinforced Concrete Construction.



IG. 4. EXTERIOR OF LINDEKE-WARNER BUILDING.

Fig. 4 is an interior view of the second charge on the same face. At one end, at the extreme top, a 6-ft. canti- a very good view of the flat ceiling, which is a feature of the system, and the enlarged heads of the columns.

The inventor, who claims economy as one of the most striking features of his system, states that the advantage is almost directly traceable in nearly every instance to the fact that the ceiling obtained is flat, and not ribbed with girders. In fact, it was that detail in particular that led to the invention of the system. This is very noticeable in the case of the floor forms, which in the "flat slab" system consist of nothing but a flat support, making the amount of material required considerably less than in the "beam and slab" system. A rough estimate of the saving of the "flat slab" system, as claimed by the inventor, is 10 per cent. of the total material used for forms.

An example of the remarkable rate of speed which can be reached on this system is the Lindeke building, above referred to, in which the whole of the concrete work was done in less than four months, which means at a rate of over 2,000 sq. ft. per day, including all shifting of forms.

We are indebted to Mr. C. A. P. Turner, A.Am.Soc.C.E. of Minneapolis, the inventor of the "Mushroom" system, for the four illustrations presented, and for the foregoing details.

REINFORCED CONCRETE COAL SILOS.

THIS example of reinforced concrete was executed at Skelmanthorpe, near Huddersfield, for Messrs. Stringer and Jagger, colliery proprietors, in connection with a new coke oven plant.

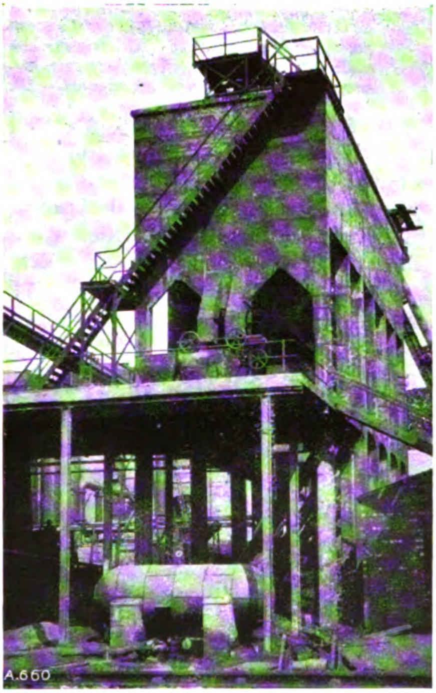
The ground upon which it was built was of a shaley-clay nature, the ground line inclining rather rapidly from end to end of the silos.

The silos are supported upon fourteen reinforced concrete columns braced together. The bases of each column are also braced to their adjacent neighbours.

The whole work was constructed on the Hennebique System by the Yorkshire Hennebique Contracting Co., Ltd., Leeds, under the direction of the Mackay-Seymour Engineering and Coke Oven Co., Ltd., of Leeds, who were the designers of the plant.

The design for these silos is unique, inasmuch as it has been arranged for the coal to discharge along one side, except in the case of the end hopper, which discharges through the bottom and the end, as shown in the illustration. The lip of the side hopper mouths is about 13 ft. above the tram rail level, and these are eleven in number, the bottom being inclined at an angle of 45 deg. from front to back. The body of the silo is divided longitudinally by a reinforced concrete partition forming two long silos, the front silo having, of course, a direct discharge, while five tunnels about 3 ft. wide and 5 ft. high with a 45 deg. pitched roof, pass through the front silo.

The hopper mouths from silos No. 1 and No. 2 are therefore alternate, and discharge on the same face. At one end, at the extreme top, a 6-ft., cantilever platform has been arranged to carry an elevator. The coal is elevated by this means to the top of the silo, when it is discharged into a continuous scraper or conveyor running longitudinally along the centre, and this in turn discharges the coal into the two long silos and the small one at the end. It is then discharged from the silos on to the ram through the side hopper mouths by gravitation and conveyed to the coke ovens.



END VIEW OF REINFORCED CONCRETE COAL SILO.

The total length of the silos is 53 ft. 10 in. and the with 19 ft. 4 in., while the height at the small hopper's end is 55 ft. 6 in. from the foundations to cornice.

The total capacity of the silos is 700 tons.

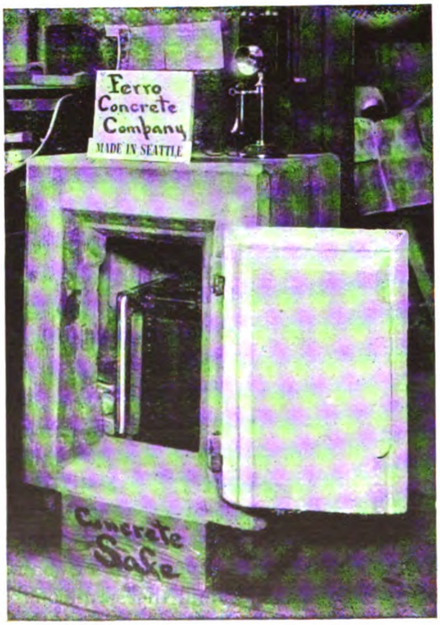
NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

A REINFORCED CONCRETE SAFE.

WE are indebted for the photograph of this novelty to the inventor, Mr. J. S. Andrews, manager of the Seattle branch of the Ferro-Concrete Construction Co., of Cincinnati, Ohio. This safe, which was built for the inventor's own use, is believed to be the only one in existence.

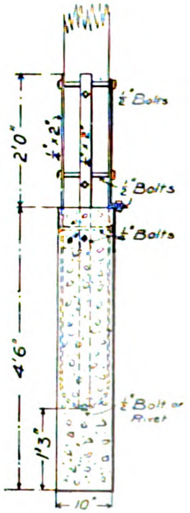


The dimensions are 2 ft. 4 in., by 2 ft. 4 in., by 3 ft. high, the walls and door being 4 in. thick, reinforced with ¼ in. twisted steel, the lock and hinges being cast in centre of wall and door, and to maintain the uniformity, the handle is of twisted steel, the same as is used in building, the safe being home-made in every particular.

CONCRETE BASES FOR WOOD TELEGRAPH POLES.

The accompanying drawing shows a concrete base for transmission line poles invented by Mr. H. H. Murray, of Bakersfield, Cal., and used by the Power Transit and Light Co. of that city.

These bases are moulded and shipped to the works ready for placing—they weigh about 420 lb. each. One base requires 37½ lb. of 2 by ¼ in. steel bar, 40 lb. of Portland cement, 3 cub. ft. of broken stone or gravel and enough sand to fill the form or mould, which is 10 × 10 in. × 4½ ft. Unskilled labour is employed in the moulding, and two men can mould ten bases in an eight hour day.



The cost of moulding is about 16s. 6d. (in English equivalents with American rate of wages) per base. In the work for the company named above, two men at 8s. per day each set five bases each in eight hours, making the cost of setting each base about 3s. 4d., but for English purposes, of course, the 8s. per day rate would be materially reduced.

The bases are sunk to a depth of 3 ft. 3 in. In many cases they are placed under poles without interrupting service by sawing off the pole, dropping it into the ground, placing the new base, and setting the sawed off pole on it and bolting up the straps.

REINFORCED CONCRETE MASTS FOR WIRELESS TELEGRAPHY.

An interesting development in the application of reinforced concrete is in course of being carried into effect for one of the companies at present interested in the problem of transatlantic wireless telegraphy. Hitherto the mast for carrying the overhead equipment has been built of steel, the production, erection, and maintenance of which is an expensive operation. At the same time, a high degree of strength at the top of the mast is imperative in order to carry the heavy weight of the gear, which approximates some three tons. The new concrete masts will comprise a tubular monolith with the reinforcing steel-work carried vertically up the sides in the concrete, and additionally armoured horizontally by circular hoops placed at frequent intervals. Arrangements have been completed for the building of such masts up to a height of one thousand feet, and they are to be of sufficient internal diameter to permit of a man ascending from the ground to the top of the structure from within.

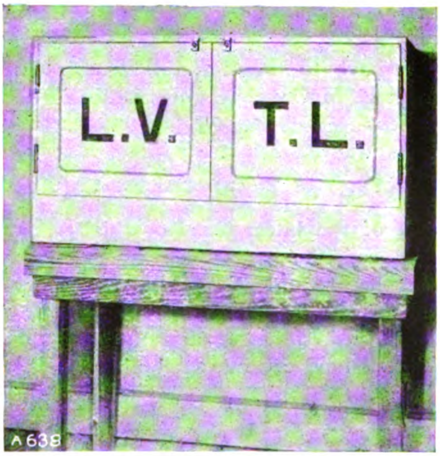
A MOIST CLOSET IN REINFORCED CONCRETE.

The closet illustrated was made of "waste cement" left from a testing—all brands mixed—and several samples of natural sand from the same source. The cement was thoroughly mixed, so as to ensure uniformity in colour.

The mortar was mixed 1 to 2 and wet enough to be filled readily into and tamped down in a ⅝-in. space. The walls are 1¼ in. thick, except the centre panels of the doors, which are only ½ in. thick. The walls are reinforced with ½-in. mesh galvanised wire netting.

The hinges in this closet were specially designed to be embedded in the walls and doors. The necessary forms for this closet can readily be made by any carpenter, and consist of an outside form or box, without top or bottom, and two inside forms or cores, which are simply boxes with tops but no bottoms. As the closet is cast face, or front down, the top of the forms means the back of the closet. When the forms are in position, there must be 1¼ in. clearance around each core, top, bottom and sides.

The doors are cast first by filling in a frame of the proper dimensions, laid on a pane of glass or other flat surface which has been oiled. The hinges are placed by marks on the frame and secured to it by small brads before the mortar is filled in. The same form answers for the two doors by simply reversing the position of the hinges. If made like those illustrated, the hinges must be "right" and "left."



Moist Closet Closed.

When hard enough to stand handling, the two doors are placed, in their proper relation, face down, on a flat surface, and the outer box form placed around them. The edges of the doors are covered with several thicknesses of oiled paper, and the cement mortar filled in around them level with the doors, making the layer of mortar just 1¼ in. thick. The inside forms are immediately placed in position, open end down, and are supported by the doors, which are sufficiently hard. If correctly made they will reach to within 1¼ in. of the top of the outer form, and there will be an open space of 1¼ in. all around each core. The mortar is then filled in around and over these cores and smoothed off even with the top edge of the outer form, this top layer forming the back of the closet.

Of course, the placing of the reinforcement adds slightly to the detail of these operations. The doors and the back are filled in two layers with the wire placed between. The wire for the sides, in one piece, is placed in position and kept in the middle by strips of ½-in. board, which are moved along or taken out as the mortar is filled in.

The shelf cleats are provided for by longitudinal strips on the ends of the core boxes, in widths equal to the distance desired by the cleats. The space between, when filled with mortar, makes the cleat.

We have to thank the inventor, Mr. Ernest B. McCready, of the Lehigh Valley Testing Laboratory, for the illustrations and information.

REINFORCED CONCRETE FOR REPAIRS.

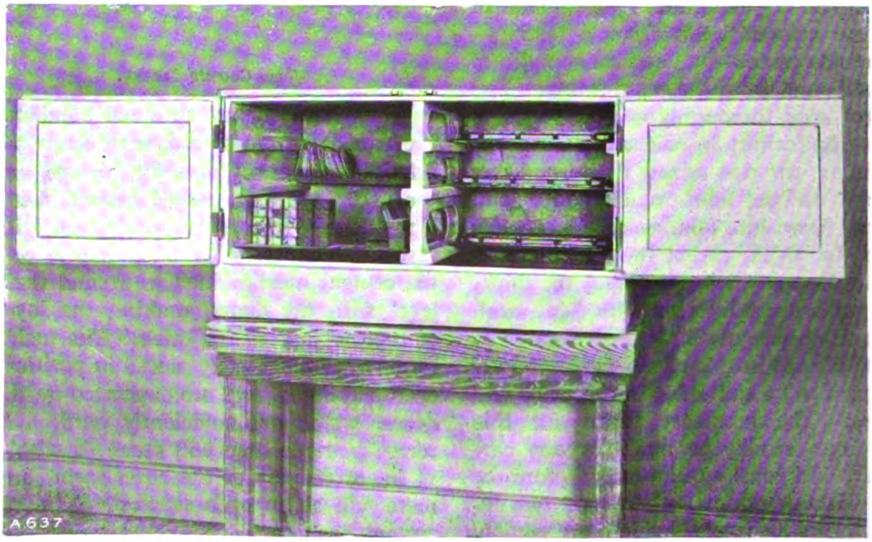
One of the latest uses to which reinforced concrete has been applied is the strengthening of brick and other masonry arches, whose stability has become impaired by the lapse of time and the effects of long continued vibration.

One example of such work is represented by the Harewood bridge, carrying a main highway over the River Wharfe, between Leeds and Harrogate. The structure is a stone bridge with four arches, one of which has recently been repaired by a reinforced concrete relieving arch, under the direction of Mr. F. G. Carpenter, the surveyor to the West Riding Yorkshire County Council.

Two arches of Crambeck bridge, near Malton, have been similarly treated, and a series of brick arches is in course of treatment at Bristol.

REINFORCED CONCRETE IN COAL-MINING.

We understand that in the Collieries of the Harton Coal Co., of South Shields, some underground tanks have recently been completed in reinforced concrete, for the collection and storage of water accumulating in the workings. The tanks, which are on the Hennebique system, are situated some 1,600 ft. below surface level, and the construction took place under difficulties, owing to the fact that the gallery was only 18 in. wider, and 15 in. higher than the tanks themselves. This new use for reinforced concrete should command the attention of all colliery owners and their engineers.



Moist Closet Open.

CORRESPONDENCE.

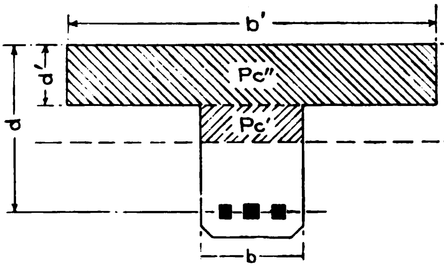
Under this heading we invite correspondence.

THE REINFORCED CONCRETE COMMITTEE.

DEAR SIR,—The writer has read with considerable interest the report of the Committee on Reinforced Concrete authorised by the R.I.B.A., which appears in your July issue. It is hoped that the following remarks on the design of T-beams may be interesting. They were inspired by the footnote on page 183, to the effect that there is no satisfactory method of determining the width of floor slab that may be considered as acting with the web.

The one uncertain element in the determination of the width of slab is the distribution of stress over the width b', but since the formulæ given assume that the intensity of stress in any horizontal plane in the flange is constant across the width, the following solution is offered. This is based on the fact, pointed out in 1903 by Mr. A. L. Johnson, that the amount of stress that may be put in the flange is limited by the shearing strength of the concrete.

Since the horizontal tensile stresses that may exist in the concrete are not to be considered, the shearing stress at any section is constant between the neutral axis and the plane of the metal reinforcement.



Using the notation of the report and in addition calling the stress in flange $= Pc''$ and the stress in web $= Pc'$. we have $Pc' + Pc'' = t \times A_t$. (Omit Pc' if axis is in flange.). $\sigma =$ Allowed unit shearing stress in concrete.

The total shearing stress on a horizontal section of the web below the neutral axis from the nearest support to the point of maximum bending moment must then $= t \times A = Pc' + Pc'' = \frac{1}{2}bl\sigma$. Where $\sigma =$ shearing stress in the concrete at the end of the beam (the shear varies uniformly from zero at the centre to a maximum at the end). Assuming a uniformly loaded beam where the maximum moment is at the centre of the span we have $Pc'' = t\,At - Pc'$, in which Pc' is a determinate quantity from the conditions of the problem.

Pc'' may be expressed in terms of $b'd'$ and c.

$$Pc'' = \frac{b'd'}{2}\left(c + c\left(\frac{Kd-d}{Kd}\right)\right) = \frac{b'd'c}{2}\left(1 + \frac{Kd-d'}{Kd}\right)$$

also

$$Pc' = \frac{bc}{2Kd}(Kd-d')^2.$$

Substituting in the equation $Pc'' = \frac{1}{2}bl\sigma - Pc'$ we have

$$\frac{b'd'c}{2}\left(\frac{2Kd-d'}{Kd}\right) = \frac{1}{2}bl\sigma - \frac{bc}{2Kd}(Kd-d')^2,$$

from which

$$b' = \frac{bl\sigma}{2d'c}\left(\frac{Kd}{2Kd-d'}\right) - \frac{b}{d'}\left(\frac{(Kd-d')^2}{2Kd-d}\right).$$

If it is desired to omit Pc', the value of which is small, we have with sufficient accuracy for most purposes

$$b' = \frac{bl\sigma}{2d'c}\left(\frac{Kd}{2Kd-d'}\right).$$

Investigation along similar lines should also be made to determine the ability of the vertical planes of attachment of the wings to transmit the amount of compression in them.

JOHN E. CONZELMAN, C.E.

St. Louis, Mo., U.S.A..
July 24th, 1907.

THE REVISED BRITISH STANDARD SPECIFICATION FOR PORTLAND CEMENT.

SIR,—I have read with interest the leading article in the September issue of CONCRETE which deals with and criticises the revised British Standard Specification for Portland cement.

As a member of the Committee responsible for the compilation of the Specification, it is gratifying to find that in your opinion the Specification is likely to meet with general approval.

As you state, the setting time of Portland cement is still a controversial point, and I venture to think that whilst it is most important to have some definite method of ascertaining and recording the final "set" of cement, it is of yet more vital importance to ascertain when the initial set of cement begins.

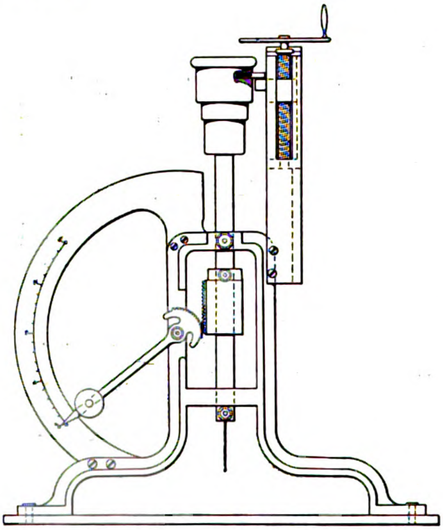
I do not propose in this letter to enter into any scientific description of what happens when Portland cement begins to set, but I think it may be taken as a generally accepted fact, that no user of cement can continue to mix up or work cement after the initial set has commenced, without serious injury to the work he is engaged in.

At present he receives no help from the British Standard Specification to enable him to ascertain when the initial "set" has begun, but I think it is quite possible to devise an instrument and make a formula which when applied to neat cement in the testing room will serve as a guide and protection to the engineer and consumer in determining the setting time, in the same way as in the case of tensile strain or other tests.

I agree with you that the present description of when cement is set, viz.: when the needle fails to make an "impression," is of very uncertain value.

As you say, What is an impression? Surely it depends upon whether the observer has strong or weak sight, or whether he views it with the naked eye or through spectacles, and further than this a great deal depends, even with the British Standard needle, upon the hand of the operator.

A slight pressure or otherwise is easily obtained if the operator leans in that direction.



This leads me to say that the method of ascertaining the initial and final setting of cement should be of such a character as to be a mechanical one and not subject to the will of the operator.

Further, that the "impression" should be a measurable quantity and recorded automatically.

With these views in mind, a large number of experiments have been carried out, and as a result I have devised an instrument as per enclosed sketch, by means of which the initial and final setting time of cement can be ascertained and measured, and a Standard formula arranged accordingly.

The experiments were so directed that the results should agree, as far as practicable, with the results obtained with the British Standard Needle at present in use, and the endeavour was to obtain a needle of such size and carrying such a weight that whilst agreeing with the final set of the British Standard Specification, it should also be capable of indicating and recording the initial set of the same sample of cement.

It was found that the success of this depended not only upon the size of the needle and the weight, but also upon the diameter and thickness of the mould containing the sample of the cement to be operated upon.

Pats or moulds of different thickness and diameter gave varying results.

The size of the needle finally decided upon is 1 mm. dia. and carrying a total weight of 400 grammes.

The cement mixture is placed in a mould of 40 mm. dia. and 20 mm. deep.

Having installed the instrument and adjusted the pointer at zero, with the needle just touching the surface of the cement mixture in the mould, it will then be seen that at the side of the instrument is a screw surmounted by a small wheel, and that this screw carries a nut with a small projecting arm which carries the weight of the needle bar, but is in no way attached to the needle bar.

When the small wheel is rotated so as to lower the needle, the needle will at first completely perforate the cement mixture in the mould and the pointer will record the extent of the perforation as 20 mm.

So soon as the needle fails to perforate the sample beyond 15 mm. then the initial set has begun.

The final set is ascertained in exactly the same manner, and when the needle fails to perforate more than 2 mm. than the final set has taken place and the time occupied in both operations can be noted.

The needle falls by its own weight, and the object of the screw and wheel is only to prevent any sudden dropping or any pressure from above.

The reason that 2 mm. is fixed as the limit of perforation for final set is because in mixing up a sample of cement for testing, what may be termed a "scum" or cream rises to the surface, and this will continue to show a slight impression or perforation for some time after the real and final set of the cement has taken place.

The British Standard Specification not having any initial set test, it was necessary to use a Vicat Needle for comparison, and the result of a very large number of tests, which will in due course be submitted to the Standard Committee, proved most conclusively that the above-described instrument and the Vicat Needle gave identical results for "initial" set.

The British Standard Needle gave slightly slower final set tests, but this is due to the difficulty in saying when the impression ceased to exist, and particularly because the so-called "impression" was unduly prolonged owing to the existence of the "scum" or cream on the surface of the mould.

If the mould be turned over and the needle applied to the other side, the difference is apparent, but the objection is overcome by fixing the limit of perforation at 2 mm.

In devising an instrument as described, the object in view was to provide a reliable and mechanical contrivance which in its working would eliminate the human element and by preventing difference of opinion arising prove equally useful to manufacturer and consumer.

C. H. WATSON.

Greenhithe,
September 28th, 1907.

RULES AND REGULATIONS.

The necessity of framing special regulations for the construction of work in reinforced concrete is being generally recognised by the public authorities and fire insurance offices, but it is quite exceptional to find a firm of specialist purveyors preparing a schedule of Rules in the form of a Handbook of Instructions for their inspectors and foremen.

The Trussed Concrete Steel Co., of Detroit, U.S.A., have issued a booklet with such instructions, the majority of which we reproduce, as a most useful guide to all engaged in the management of reinforced concrete work.—ED.

A HANDBOOK OF INSTRUCTIONS FOR REINFORCED CONCRETE.*

Issued by the Trussed Concrete Steel Co., of Detroit, U.S.A., 1907.

Superintendents and Inspectors are required to become familiar with and carefully follow out these instructions for erection and inspection of reinforced concrete structures, and see that every detail of the work is carried out in strict accordance with the same.

DUTIES OF INSPECTOR.

An inspector is required to be on the work during the erection of forms, the placing of reinforcement, the mixing and placing of concrete and removal of forms. He represents the superintendent or engineer in charge and will be held responsible for the correct performance of the work assigned to him.

He must watch the progress of the work carefully and continuously, making a record of the amount of work done each day and the manner in which it is done. He is required to become thoroughly familiar with the plans and working drawings of the work on which he is engaged, so that he may intelligently perform the duties entrusted to him. He may be required to fill in a daily report sheet on printed forms furnished for the purpose, giving the location of the work done, the number of batches mixed and placed, the proportions used, the arrival of material and all such other information as will assist in making a concise and accurate record of the progress and cost of the whole or any part of the work.

DRAWINGS.

Drawings must be carefully studied. If any part of them seem inconsistent or wrong in any detail, communicate immediately by long distance telephone or telegraph, with engineer or architect and Home Office of Trussed Concrete Steel Company. Do not proceed with the work unless the error is rectified.

FORMS AND CENTERING.

(False-work.)

General.—All form boxes must be true, rigid and temporarily braced to withstand handling and erection. They should be carefully re-examined just before placing concrete.

In erecting form-work great care should be taken that the boxes are plumb and that they are set true to line, without winds or twists. Otherwise the concrete will not only be of bad appearance but must often be removed and corrected at great expense.

All centering and supports must be properly braced and cross-braced in two directions, especially to resist storms and high winds.

Forms and centering must be strong enough to easily carry the dead weight of construction as a liquid and the load due to placing, without any deflection.

All joints must be fairly tight, so as to prevent leakage of the liquid mass, which would cause honeycombing in the concrete.

The arrangement of forms and centering should be such that the slab centering and sides of beams and column forms may be removed first, and then allow the bottoms of beams and girders to be supported for a longer time.

Place bevelled strips in the form boxes to finish column and beam edges.

Cleaning.—The foot of each column box must remain open on one side for joining and adjusting the reinforcement, but especially for inspecting and cleaning out just before pouring the concrete. Sawdust and other foreign matter can be removed from the steel and the column sides with a hose. In fact all the false-work should be thoroughly cleaned before any concrete is placed on same.

It is of vital importance that the above-mentioned opening remains open until the first wheelbarrow with rich concrete or mortar is waiting above.

Be especially careful that no wooden blocks, shavings, saw dust, etc.. remain in the form when the concrete is placed.

Bearing of Supports.—Where the centering posts come on soft ground, or a tile floor, their load should be distributed by means of scantlings or short piles; otherwise the supports are sure to be pushed into the ground, causing a sag and possibly cracks in beams and floor slabs. All uprights should set upon a double set of wedges cut from 4 x 4 in. scantling.

Economy.—In building forms and centering, remember that the cost of timber is a large item of the total cost. With a little ingenuity and forethought this work can be most always arranged so that repeated use is made of each piece of timber.

Wedges.—Wedges and wire ties are most convenient in tightening up false work and removing it again afterwards without shock or vibration.

---

* Note by the Compilers.—Superintendents, Inspectors and Foremen must read carefully the following instructions. Ignorance, on their part, of these instructions, is an open declaration of their incompetence and unfitness for holding their position.

Protection.—After the false work is once placed it should be protected against severe temperature changes and against rain or snow. If it is necessary to leave the form-work empty for any length of time, then, before pouring the concrete, it should be gone over again carefully, the shrinkage joints repaired and the bracing and supports tightened up. In warm weather wet the forms before placing concrete, otherwise the lumber will absorb the water in the concrete and cause honeycombing.

Lumber.—Pine or spruce is far superior to hemlock for false-work. Hemlock when exposed to the weather becomes absolutely unreliable.

For form boxes of columns or beams 2 in. timber is recommended: for floor slabs 1 in. boards on 2×8 in. joists spaced 16 to 24 in. apart, according to thickness of slab; for posts 4×4 in. spaced from 3 to 8 ft. apart, according to the height and the dimensions of beams and slabs; for bracing and cross-bracing 2×4 in.

Clamps and Nails.—The skilful superintendent or foreman may be recognised by the scarcity of nails he uses. Column boxes should be securely clamped and beam boxes so framed that the floor joists practically hold the sides without nailing. If the removal of centering necessitates the use of the long prying crowbar with three labourers at its end, the foreman should be fired.

Organization.—There should be one foreman, at least, for every twenty carpenters, and a head carpenter foreman in charge of all false work.

(See "Removal of Forms and Centering.")

REINFORCING STEEL.

As steel is received it should be checked, assorted and stored in such a manner that those portions needed first may be reached without disturbing the remainder. If there is any confusion in the marks, report the discrepancy immediately to the Home Office of the Trussed Concrete Steel Company.

In large work, a man should be appointed whose sole duty is to look after the receiving, checking and storage of steel.

All steel must be free from loose scales, but a thin film of rust will not be objectionable. Bars covered with loose or scaley rust must be cleaned with a stiff wire brush.

Bars should be free from oil or paint as either will lessen the adhesion of the concrete.

Steel should be properly braced, supported and otherwise held in position so that the placing of the concrete will not change it.

The inspector must see that the correct number and size of reinforcing bars and anchors are used and that they are spaced and placed strictly according to plans and working drawings. This is of vital importance and should be looked after with the utmost care and checked over personally and finally just before pouring the concrete.

All protruding bars from piers, columns, beams and slabs, to which other bars are to be spliced and which will be exposed to the action of the weather for an indefinite period, must be protected from rusting by a coat of thin, neat cement grout.

All ordinary bending will be done cold, but it is very important, especially in bending the large bars, that the bending force be applied gradually, and evenly and not with a jerk. A jerky action is likely to snap or crack the best steel.

Should any bar be broken it must be laid aside and another bar of the same length and cross-section procured without delay.

Placing of Steel in Columns.—Leave one side of the box open for the adjustment of the steel. Wood templates should be used to properly space the bars at the bottom and top. If bars are bent at the top to form a connection with column above, another template should be used to make sure that the connection will fit. The bottom of bars should have a direct bearing on the steel of the column below. Pipe sleeves are used to insure this bearing.

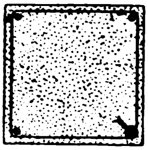
Very often additional splice bars are used. These should be placed absolutely vertical.

The column reinforcement is usually composed of : (1) four or more Kahn bars, securely wired together at the bottom and often at regular intervals; (2) round rods tied or hooped with small rounds or flats.

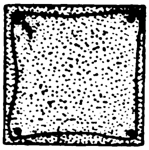
If Kahn bars are used the diagonals should be pulled out so that they are at right angles with the main member. Take special care in placing the wire, which should be tight and in exact accordance with details. The vertical steel should be uniformly 1½ in. or 2 in. from the forms.

If round rods are used they must be absolutely vertical, straight and true. The hooping must be tight, rigid and regular. Care must be taken that the connection at bottoms and top are correct.

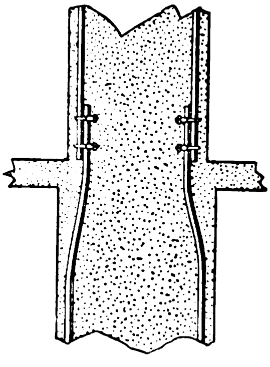
The wire ties or hoops must always fit exactly as this



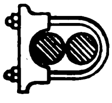
and not as this.



If sleeves are not used or obtainable for connection, then use regular cable splice, bolted as tightly as possible.



Note.—Hooping, Ties, &c., are not shown on this sketch.



If extra splice rods are called for they should never be omitted.

Owing to the large amount of steel at the column splice, especial care should be taken in its placing. This is the most important part of the columns, and the strength of the structure depends very greatly upon the correct placing of the steel.

PLACING STEEL IN BEAMS.—First lay 2 in. of concrete with small stone in the bottom of the beam box and then place the reinforcing steel on top. The centre of the bars should not be less than 2 in. from the bottom of the beam in every case.

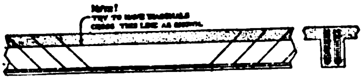
The diagonals must be properly bent up at an angle of about 45 degrees from the main portion of the bar, or at any rate, they should be bent exactly as shown on drawings.

See that bars have proper bearing at ends, on the column, girder or wall. The inspector should personally see and approve every bearing or connection of the steel just before it is covered with concrete.

Whenever (top) continuity bars are shown, be sure that they are put in exactly as shown on drawings. These top or continuity bars should be as near the top of the finished concrete floor as possible, in order to obtain the greatest strength. The diagonals of the continuity bars must be bent at the usual angle of 45 degrees and placed pointing downward into the concrete.

The placing of wood or iron inserts should never interfere with the placing of the reinforcing steel. The reinforcing steel is first and foremost in importance.

It is very desirable that the diagonals extend upward sufficiently far to cross the horizontal line between the underside of the slab and the bottom of beam. As :



PLACING STEEL IN SLAB AND TILE JOINTS.—In placing steel bars in floor slabs and in concrete joists between tile, lay ¾ in. of concrete first, and then place the bar in position. Take the same precautions as described under "Placing Steel in Beams," with regard to bending the diagonals, and also with regard to placing continuity bars over girders and bearings.

A very little experience should teach a superintendent where continuity bars are needed, even if they have been omitted from the drawings, and in case of such omission if it should appear that continuity bars are needed, communicate with the Main Office by telegraph or telephone, if necessary, but do not omit them from places where common sense would indicate that they are required.

CEMENT.

STORING AND INSPECTION.—Cement must be stored at the building site in such a manner as to permit easy access for proper inspection and identification. The building used for same must be raised from the ground and thoroughly weather-proofed to protect the cement from moisture of any kind.

Only the best grades of Portland Cement should be used, and all cement must be tested before it is used.

If the results of tests are not satisfactory to the requirements of the American Society of Testing Materials, then the cement should be rejected and removed immediately from the ground.

If it is to be tested on the ground, specific directions and specifications for this purpose will be furnished in each particular case. In order to have a fair assurance that the cement has not suffered during transit to the mixer, the inspector must see that the packages are unbroken, and that the cement is of uniform colour and absolutely free from lumps.

METHOD OF SAMPLING.—Reliable and trustworthy results are only possible after extreme care and caution have been exercised in sampling. Samples on reaching the laboratory are submitted to the most careful and thorough scientific examination, and it is of the utmost importance that the laboratory have the conscientious co-operation of the sampler in order to guarantee reliable results.

We wish to emphasize as forcibly as possible the responsibility incumbent upon the sampler, and that absolute trustworthiness, honesty, and patience are indispensable qualities. In all sampling every care and precaution must be exercised.

An efficient and satisfactory method of sampling a car of cement to insure fairly representative samples consists of taking samples from every barrel and combining five samples thus obtained into one composite sample, considered as representative of fifty barrels. This obviously gives us one composite representative sample for every fifty barrels contained in one car.

In the execution of this plan we advise that during the unloading of the car, one sack in every forty be consigned to a separate pile to be understood as the Sample Pile: and orders given that sacks contained in this pile be unmolested until thoroughly sampled. To each sample sack as it comes from the car, is attached an appropriate tag upon which is written the car number and such other data as may be deemed necessary to identify it without any confusion. The laboratory gladly furnishes these tags, which have been especially designed for this purpose.

We consider each sack in the Sample Pile as the representative of every tenth barrel contained in the car, and in sampling we combine samples from the first five, then from the second five, third five, etc., sacks, and consider the samples thus obtained as combined composite, representative samples of 500 barrels.

For further details and information regarding the testing of materials entering into concrete, communicate with the Michigan Technical Laboratory, Detroit, Michigan.

SAND.

Clean, coarse sand should be used. The cleaner the better. Sand which is too coarse is perhaps not of the best quality for good concrete, but of the two extremes there is less likelihood of trouble from very coarse sand than from the reverse. Fine sand even though clean is difficult to properly mix with the cement and may give bad results.

The presence of clay or loam in sand in any considerable percentage renders it unfit for use. The percentage can be determined approximately by putting a sample of the sand in a bottle and shaking it with water. The grains of the sand will settle to the bottom first, leaving the dirt, loam or clay on top. It can then be measured, and should there appear to be more than 5 per cent. of foreign matter in the sand, it should be rejected.

STONE AND GRAVEL.

In undertaking any piece of construction work, find out where a sufficient supply of suitable stone can be found. Broken trap rock if clean and free from stone dust will give the best results in concrete. If broken stone cannot be had in the vicinity or without great cost, clean coarse gravel may be used instead. If the gravel is mixed with sand or dirt, it should be screened before using. The quarries selling broken stone sometimes attempt to dispose of broken stone mixed with quarry refuse, stone dust, etc., and each carload should be carefully inspected and rejected if the material is not perfectly satisfactory and of such quality as will give first-class results when mixed in concrete.

Size of stone or gravel depends upon the size of the concrete members. In small beams, columns and slabs, the maximum diameter of each piece should be about ¾ in. In larger members 1¼ in. For very large and massive walls or footings still larger sizes may be used.

MIXING OF CONCRETE.

Water.—Only fresh, clean water, free from acids or strong alkalies shall be used. Do not put the water in the mixer with a hose. This invariably results in a lack of uniformity in the mix as regards its fluidity. Certain batches come out too wet, others too dry. The water must be measured, and when the proper consistency has been found use the exact same amount for each batch.

Proportion.—All concrete, for beams and slabs shall be proportioned of one part Portland cement, two parts sand and four parts of broken stone or gravel, and for columns—one, one and one-half, and three, unless otherwise specified.

Mixture.—All concrete shall be machine mixed, using a batch mixer. All materials should first be thoroughly mixed dry, after which plenty of clean water is added, so that the resultant mixture becomes what is known as a wet or mushy mixture. All mixing should continue until the concrete is uniform. A competent foreman must be in constant attendance at the mixer to give his approval of every batch that leaves the machine.

Here again it is of vital importance that every precaution and vigilance be exercised continuously so as to be sure, beyond any doubt, that not less than the specified proportion of cement goes into the mixer. A double check system is absolutely necessary in this matter.

Have one man in sole charge of putting the cement in the mixer. This man should be of sufficient intelligence to understand the responsibility of his work, and must be made to realize that a single batch of concrete not containing the proper amount of cement may endanger life and property.

The man in charge of the mixer should also observe the dry batch and see that the cement has not been overlooked.

Mixing in High Temperature.—In very hot weather the broken stone, and the sand when exposed to the sun often become so heated as to cause certain kinds of cement to set almost immediately. This has been known to occur in the mixer, causing concrete to cake and stick to the mixer to such an extent as to interfere with its proper working. Upon any sign of this, have the stone wet with cold water, and if necessary, erect temporary shelter for both the stone and sand.

PLACING CONCRETE.

General.—All forms must be absolutely clean and free from shavings or foreign matter before any concrete is placed.

All concrete must be deposited in forms within ten minutes after leaving mixer.

Before commencing to pour concrete, the reinforcement for the entire floor should be directly at hand with that for the columns below all in place. The placing of steel can then be carried on with the concreting but kept just a little in advance.

If a tank or hopper is used for receiving the mixed concrete, great care must be taken to see that the hopper discharges uniformly and that mixed concrete does not accumulate and lie in the tank until it has set.

Places for Stopping Concreting.—When concreting is once commenced it should be carried on rigorously to completion, if possible. If concreting must be stopped before the entire portion is completed, then the place for stopping should be determined upon by either one of the following two methods, although a great difference of opinion among experts exists as to this point.

Method No. 1. For Stopping Beams and Girders.—Stop concrete at the centre of the beam with a vertical plane at right angles to the direction of the beam.

For Stopping Slabs.—Stop the concrete at the middle of the span, making the plane perpendicular and at right angles to the direction of the span.

Method No. 2. For Beams and Girders.—Stop the concreting in beams and girders directly over the centre of the column, making a vertical joint and allowing one-half the column to become the bearing surface for the future adjoining beam.

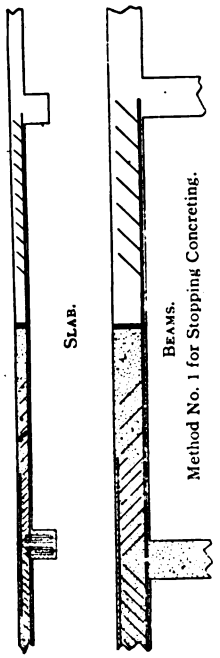
For Slabs.—Break the concrete directly over the centres of the beam, making a vertical joint and allowing for the future adjoining slab.

In either of the above-mentioned methods and in every case there must be installed a sufficient number of continuity bars to tie the beam or slab to the opposite side. If there is no beam coming directly opposite the finished beam it should be connected well with the future opposite slab with steel.

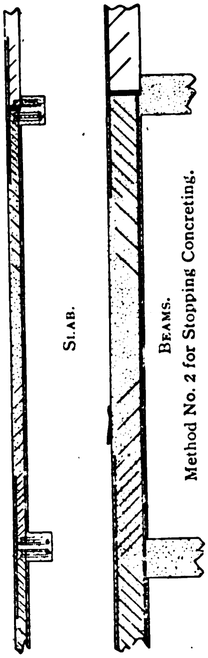
In no case shall work be terminated on beams or floor slabs in any other places than indicated above without special permission from the engineer in charge of the work, and we would advise that the Home Office of the Trussed Concrete Steel Company be consulted.

In no case shall work be terminated in beams or floor slabs where future shearing action will be great, as near the ends or directly under the concentrated load.

These suggestions are herewith illustrated.



Method No. 1 for Stopping Concreting.



Method No. 2 for Stopping Concreting.

In concreting columns, girders, beams and slabs, if for some unforseen cause the work must be stopped at places differently located from those designated herein, the old surface must be roughened up and thoroughly covered with 1 : 1 cement mortar before concreting is continued.

Special Inspection.—When concreting is in progress have the man who is stationed at the hopper instructed to constantly inspect the general appearance of the mixed concrete as it is poured into the wheelbarrows. He must see that it is of the proper consistency and fluidity, that no foreign substances, such as wooden blocks, chips, etc., have found their way into the mixture. Also he must be able to judge by the appearance as to the proper proportions having been used.

All beams and slabs must be filled to the top surface in one continuous operation, that is from bottom of beam to top of floor construction. Also the concrete on top of tile floor construction must be placed at same time as concrete joists. Unless this is done the floor will be greatly weakened, and might have to be removed at great expense.

Spading and joggling the sides of girders, beams and joists is necessary to obtain nice appearing surfaces.

Filling Columns.—The greatest caution and vigilance must be exercised in filling columns. To start with, it is not sufficient to inspect and clean out the foot of the column box just before pouring, but look through it while open and lighted below, and assure yourself that no piece of wood or tile has fallen in and wedged somewhere.

Columns should be filled six to eight hours ahead of beams. This is important.

It is recommended and considered excellent practice to fill the lower two or three feet of the column with 1 : 1 cement mortar, but if this is done or not done, it is absolutely necessary to expel bubbles of air by constant puddling or joggling the concrete with a rod, wedge-shaped at the bottom, and heavy enough to sink the concrete with ease.

In columns greater in height than 12 ft. the entire column should not be poured from the top; pour about one-half in such case from an intermediate pocket. Constant puddling, however, is equally necessary in this case.

The pouring of a column must be a continuous operation to the bottom of the beam or girder.

Caution.—Particular attention is called to the fact that concrete, after it has begun to set, must not be disturbed. If walked on or wheeled over during the time of setting, the set will be incomplete or may be entirely destroyed. Workmen are likely to pay little attention to this, and constant watching on the part of the inspector is necessary to guard against it.

Records.—The concrete foreman must mark in ink upon the plans the date when each part of the work is concreted. This must be attended to every time concreting is done, and it must not be put off until some convenient time and then filled in from memory.

A sample block of concrete should be made from each day's work. This sample should be poured into a box about 6x6x6 in. and the box should be dated. This will serve as a guide to determine the condition of the concrete before centering is removed.

REMOVAL OF FORMS AND CENTERING.

Greatest Care Necessary.—The falsework should be removed with great caution and without jarring the structure or throwing heavy forms upon the floor. Remember that even a moderate force or weight applied to the structure with a shock may cause destructive results. The practice of ramming down the posts and thus letting everything crash to the floor must not be tolerated.

Three or four workmen should be set aside and trained for the removal of all falsework. The importance and dangers attending the work should be thoroughly impressed upon them, so that carelessness on their part would be classed as positive criminal negligence, subjecting them to probable imprisonment.

Care in removing falsework will reveal any weak spots that may exist and which may then be repaired without any damage.

Care should be taken that there is no great load on the floor at time centering is removed.

METHOD OF PROCEDURE AND TIME.—The following procedure of removing falsework is absolutely essential, it being assumed that the weather has been most favourable for the setting of concrete, that is warm and dry. In cool, damp weather it should be left in place much longer.

The time of removal of the various parts of the falsework is intended to begin when the concrete is completely placed. No exact times are intended. Before undertaking to remove any falsework, the superintendent should personally satisfy himself as to the condition of the concrete. It should not only show a sufficient degree of hardness but should ring when struck with a hammer.

At the end of not less than seven days remove the sides of the column boxes so that the columns may be thoroughly exposed on all sides and their soundness approved. The airing of concrete assists the time of setting to a remarkable degree and should always be encouraged.

At the end of not less than two weeks loosen lightly the wedges from posts supporting floor slabs, allowing all posts to lower away from the overhead floor about one or two inches. An examination should then be made of the work and the falsework should be left in this condition for at least twenty-four hours. Then gradually remove the shores, joists and sheathing supporting floor slabs.

Remove sides of beams and girders, allowing the bottoms to remain supported. (This is important.)

Temporary shores should be installed under the floor slab immediately after the original falsework is removed. These temporary shores should be left in place for at least a week. The quantity of lumber tied up in this manner is not very considerable, and the proper aging and hardening of the concrete is very much helped by the exposure to the air. After a period of one week, the temporary shores can be altogether removed; in case the newly-made floor is not to be loaded with heavy materials. If it is liable to loading of any consequence the temporary shores should be left in place so long as such a possibility exists.

Shores should not be removed from under side of beams in less than three weeks.

Removal of forms and centering should never be started until the concrete is thoroughly set, and has aged to give it sufficient strength to carry its own weight, besides the live load which is likely to come on the work during the course of construction. In fairly warm weather this may be about ten days.

GENERAL.—In all cases the approval of the architect or engineer in charge must be obtained before removing the falsework.

The test cubes should be consulted when determining upon the time to remove falsework.

CEMENT FINISH.

Do not attempt to put on cement finish on top of floor slabs which have been previously concreted if the finish is less than two and one half inches in thickness, as it will not properly adhere to the body of the concrete. If an inch finish is specified on the floor, the finishing must be done at the time of laying the concrete, in order to have it adhere. Where the finish is put on after the floor slab has been constructed, the greatest care must be taken in cleaning the surface of the floor of all foreign matter and dirt, and the clean surface must be thoroughly grouted, in order to obtain the best possible cohesion.

A kind of neat cement (without any sand) will aid in connecting the finish with the main concrete.

Finish should never be less rich than 1 : 2 and preferably 1 : 1. A coarse gritty sand is best; a fine round sand is very bad.

CUTTING FINISHED CONCRETE.

The superintendent on the ground must, under no conditions, allow other contractors to cut into the finished reinforced concrete work. This refers especially to the plumbers, carpenters, steam fitters, electricians, etc. Should it be necessary to bore holes in the floor or make slight cuts on beams and slabs, then permission for doing this should be obtained from the engineer in authority.

FINAL CAUTION.

The superintendent of the work should understand thoroughly that the responsibilities placed upon him are very great and most important. Lack of care on his part may endanger the entire structure, causing possible loss of human life. Disobedience on his part in following the drawings or these instructions, subjects him to immediate and disgraceful dismissal. Carelessness on his part may subject him to the public charge of criminal negligence and imprisonment.

The superintendent is requested to take absolutely no orders from the owner or parties to whom he is not directly responsible, which may in any manner contradict the instructions herein contained. The plea of having followed instructions given by outside parties is absolutely no excuse for his negligence.

NOTE.—The Sections entitled "Concreting at Night; Concreting in Freezing Weather; and Reinforced Concrete Joist and Tile Construction," have been omitted.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume II. No. 6. JANUARY, 1908.

EDITORIAL NOTES.

A "CONCRETE INSTITUTE."

SINCE some considerable time those interested in concrete and reinforced concrete, both professionally and industrially, have felt the absence of any Institute or Society devoted particularly to the subject they have at heart. It has thus been mooted that an Institute should be formed, known as "The Concrete Institute," which would accord its attention entirely to concrete and reinforced concrete.

Although the circumstances are not exactly alike, it should be remembered that those interested in iron and steel have long had an Iron and Steel Institute, where the professional man in practice, the scientist, the maker of steel and the constructional engineer meet for the consideration of subjects of mutual interest, and the advancement of the production and application of these materials.

The formation of a Concrete Institute, we understand, has not only the sympathy of the civil engineer and architect engaged in work where concrete and reinforced concrete play an important part, but it also enjoys the advocacy of a number of those industrially concerned with the subject. Various consultations have taken place, and it is almost safe to predict that the Institute will shortly be formed with an influential council, and a not unimportant membership.

It is needless to say that this journal welcomes the idea of such an Institute, for it has long felt that existing societies and institutes do not, and in fact cannot, accord to concrete the attention it merits, and that where some attention is accorded, even if only to a very moderate degree, it has already become a strain upon the work and resources of those bodies.

The subject is also one that essentially requires the co-operation of the engineer, architect, scientist and industrial specialist, and thus calls for an Institute in which all parties concerned can meet on a friendly footing.

We wish the proposed Institute an early formation and every possible success, and trust that apart from adding to the world's knowledge of the subject, it will stimulate interest in the uses of concrete and reinforced concrete, and encourage their economic application.

THE LOCAL GOVERNMENT BOARD AND REINFORCED CONCRETE.

IT is with considerable interest that we hear that quite a number of municipal technical officials are now actively engaged in considering the advisability of some arrangement being arrived at with the Local Government Board for putting reinforced concrete on an equal footing with brick, timber and cast iron.

Our views we have already frequently given, namely, that there is occasionally a certain risk during the period of construction. *i.e.*, during the removal of the necessary forms. The full loan period need thus, if necessary, only be granted subject to a certain number of days having elapsed after completion, or after specified tests have been undertaken. Given completion and good workmanship, under skilled and conscientious supervision, there seems to be not the least reason why there should be any differentiation between reinforced concrete and ordinary building materials, and thus, the sooner the present *impasse* is brought to an end, the better for the poor ratepayer, who at present has to pay for unnecessarily expensive materials and methods of construction, materials upon which the Local Government Board are for all practical purposes setting a premium.

CONCRETE AND FIRE PREVENTION.

MORE than ten years have elapsed since the great Cripplegate Conflagration of 1897, which served as a turning point for so much relating to fire prevention.

Not the least important of the technical changes since that conflagration, inaugurated by many of our public authorities and the majority of the professional men concerned, has been the systematic specification of concrete as a fire resisting material in preference to the dense terra cotta so unwisely favoured at an earlier date. In Government and other public buildings in particular, the unreliable dense hollow terra cotta block or lintel floor is being generally superseded by concrete floors, and the concrete partition slab is taking the place of the terra cotta slab except where the latter is of the character of a porous brick.

Similarly engineers and architects in private practice who take an intelligent interest in fire resistance, are applying concrete generally both in business and domestic structures in private ownership. Thus with some few notorious exceptions the use of dense hollow terra cotta may be said to be dying out. Where clay products are used at all for floors on private property, the tendency is to use porous bricks with a backing of concrete, but, comparatively speaking, this material (which is certainly an improvement on the dense terra-cotta) is as yet only used to a very limited extent.

The tests, both of actual fire and official fire tests, have proved the efficacy of well-made concrete as a fire resistant, practically in all forms, and they have similarly proved the unreliability of the hollow dense terra cotta so much favoured in earlier days. Hence the sooner the few men who have not yet mastered this fact do so, the better for fire protection. We may, however, anticipate that modernised building laws and up-to-date Fire Office rules will eventually prohibit the use of dense hollow terra cotta altogether, whereby the personal likes of the uninitiated few will be effectively discounted.

Regarding the use of concrete as a fire resistant, there is, however, still much to learn, particularly when utilised in connection with steel as reinforced concrete, for there is no doubt that the difference of resistance shown by concrete of different aggregates is very great indeed, as also its conductivity when used for the protection of metal rods. Thus research work in this direction is much needed, and such an enquiry as that of the Special Commission on Concrete Aggregates under the chairmanship of Sir William Preece, K.C.B., referred to elsewhere, is very welcome.

REINFORCED CONCRETE ON THE SHIP CANAL, MANCHESTER.

IT has long been recognised that the Manchester Ship Canal Company, and their chief engineer, Mr. W. H. Hunter, M.Inst.C.E., have been leaders in the application of reinforced concrete, and their great reinforced concrete warehouses stand as a leading example of what can be done with this material.

Reinforced concrete is now being used on the canal estate for certain difficult foundations, and also on some work in connection with the extension of one of the lock piers, which latter instance certainly calls for special remark.

Here reinforced concrete caissons have been formed, which should serve as a model for similar work throughout the country, for they are, both practically and economically, an advance upon what has been previously done in this direction.

The caissons, which are constructed on a level quay not far distant from the lock on which they will be used, weigh up to 110 tons each. They are bodily slung into position by the aid of pontoon sheers. The voids are thereupon filled in with concrete in a proportion of 1 to 8, and the whole when complete forms a pier head of a substantiality and strength difficult to equal.

The work is of such an up-to-date and special character, that we hope to refer to it at length at a later stage, but in the meantime we desire to call attention to it as it is a unique example of what can be done with reinforced concrete.

L. G. MOUCHEL & PARTNERS, LIMITED.

AS publicly announced, a Limited Liability Company has been formed to carry on the business so long associated with Mr. L. G. Mouchel's name, and the formation of this Company is of such general interest, that we publish some of the official particulars available in another column.

As we have indicated on an earlier occasion, there can be no doubt that the thanks of all interested in reinforced concrete are due to Mr. Mouchel for the efforts he has made during the past years to popularise this form of construction, and it speaks well for the result of his painstaking efforts that his business has been so successfully developed, and can now be deservedly turned into a company of satisfactory capitalisation. Not all may have agreed with his methods, or have regarded his system of design as infallible, yet the work executed under his direction has, as a rule, been of an eminently practical character, economical, and of considerable technical interest.

It is, of course, an essentially modern departure to find the vocations of a "*Specialist in 'ferro-concrete' construction, Engineer* and *Architect*" grouped together in one phrase in the documents as indicating the nature of the business that has been turned into a Company.

The work of the Reinforced Concrete Specialist is supposed to be primarily commercial, and that of the Engineer and Architect intended to be essentially professional, yet there is no denying that the character of the work undertaken by Mr. Mouchel is frequently quite as much of an architectural or of an engineering character as it is commercial. In fact, a close analysis of the nature of the work would show that technical skill and commercial acumen have proved to be of equal importance in it.

However, whatever the specific description of the new Company's work may be, we trust, in the interests of the development of reinforced concrete, that the earlier energetic propagation of the subject may be continued by it, and that the work may receive the pecuniary reward due to a firm that has acted as a pioneer for this form of construction. Although the Company may feel the competition of various other firms more recently established, and above all, must feel the natural tendency of the intelligent engineer to do his own designing in reinforced concrete, we may anticipate a successful career for the firm, which, it should also be remembered, now also has the more active association of Messrs. De Vesian and Gueritte.

THE WRONGFUL USE OF CEMENT BAGS BEARING A SPECIAL MAKER'S NAME.

IN our advertisement columns will be found an apology from a firm of contractors, addressed to a cement maker, where the contractor finds that—unknown to himself—the maker's bags carrying the mark of Tingey's Crown Brand London Portland Cement, have been utilised for the transmission of a quantity of cement manufactured by others than the owners of the bags.

It would appear that a special brand, namely Tingey's, had been specified for two contracts, and that other cement bagged in Tingey bags had been delivered to the jobs. In this case the head of the firm accepted the responsibility of his employee, and has apologised in a manner that does him credit; but it is nevertheless to be regretted that the mistake should have occurred, and that he should have been made the victim of his employee's action.

EVERY DAY CEMENT TESTS.

WE have received an announcement from the Associated Portland Cement Manufacturers (1900), Ltd., that they have arranged lectures and demonstrations at one of their London wharves, with a view of assisting clerks of works and foremen to obtain a knowledge and experience of cement testing.

The crude tests one frequently sees undertaken with Portland Cement would be laughable were they not of serious import to the cement maker, the contractor, the building owner, and his professional advisers alike. So many of these primitive tests are entirely valueless, both in the positive and the negative sense.

We are sure that the opportunity will be welcomed both by clerks of works and foremen who have their vocation at heart, and engineers and architects would also do well to take notice of the existence of such lectures and demonstrations with the view of influencing their clerks of works to attend them. The results of some of the elementary tests put before architects and engineers by persons unskilled in cement testing are frequently so erroneous as to become timestaking, leading all too often to unnecessary and acrimonious correspondence with the contractor or cement maker, whose delivery may have been quite in order. Cement testing requires knowledge, experience and care. This fact is not as fully realised as yet, as it should long have been.

1908
January 1st.

CHARACTERISTICS OF THE CHIEF SYSTEMS OF REINFORCED CONCRETE APPLIED TO BUILDINGS IN GREAT BRITAIN.

A SUMMARY WITH TABLES.

This article on the characteristics of the chief Systems of Reinforced Concrete used for building construction in Great Britain should be read as a summary of the systems available for immediate use on the 1st. of January, 1908, and the introduction to this article indicates the basis upon which the summary has been prepared.

Perhaps the most noticeable feature in the article is the manner in which it shows the advancement in the number of Reinforced Concrete Systems actually available, compared with those in use two years back when this journal was founded.—[*ED.*]

INTRODUCTION.

In accordance with requests received from all parts of the Empire, we are presenting an article descriptive of the various systems of applying reinforced concrete to building construction in this country.

The requests which have reached us in nearly every case ask for a summary, which, in a few pages, would indicate the principal features of the various systems, but we have gone one step further, and are not only presenting the summarised description, but have prepared some tables from which the principal features of each system can be seen at a glance.

After some consideration we have divided up the subject into a number of sections, devoted respectively to beams, floors, columns, walls, chimneys, piles and pipes, and we have thought it advisable to do this, regardless of the fact that certain points necessarily find repetition under these headings.

Our principal difficulty, however, has been to come to some decision as to what should be included under the heading of "Reinforced Concrete Systems" of construction. In the first instance we had to decide whether the form of construction might be termed to be a *bona-fide* system, and in the second place whether what we were describing was actually reinforced concrete.

In arriving at the results presented, we have not been guided by any question of proprietary rights or patents, but simply by what we would term the existence of a specific process or system of design which is kept to under varying circumstances.

Regarding the decision as to whether we were dealing with reinforced concrete or not, the difficulty was primarily apparent when attempting to describe the various forms of floor construction. It was all too easy to consider as reinforced concrete work some of the excellent forms of steel frame floor construction, in which concrete plays an important part, and equally easy on the other hand to omit from our Reinforced Concrete series floors in which the reinforcement is either in the form of joists, or comprises steel sections very like joists.

We trust, however, that our selection may find the approval of the majority of our readers, for we are fully aware that the opinions are so divergent that it is practically impossible to meet the views of all. In any case, this summary must necessarily be a useful one for the purpose of rapidly arriving at a conclusion as to what is immediately available in reinforced concrete for building construction in Great Britain.

This brings us to another point which we perhaps should specially refer to *i.e.*, that we have on this list only such systems which have been actually introduced into the country, and are stated to have been operated with.

We are, of course, fully aware that new inventors, both British and foreign, are at the moment making efforts to place their ideas before this country, and to open up business, and that there are numerous systems of which this may be said, but the article we are presenting is intended to be a practical one for the immediate use of engineers and architects desirous of specifying reinforced concrete work.

In the preparation of this article a special effort has been made to accord the fairest possible treatment to the various proprietors or agents of the systems concerned. The data have been prepared, read or revised by no less than three parties who can speak with some authority on the subject, and during the course of preparation, the various specialists concerned have, as a rule, been communicated with, with a view of obtaining their observations on the subject of their own system. Where the proprietor of a system claims some specific advantage, this claim has been put forward as such, and it must be left to the judgment of the reader to decide as to whether the claim is to be maintained or otherwise.

It has been particularly pleasurable in the preparation of these notes to observe what a great advance has been made of late in the application of reinforced concrete in Great Britain, and the very fact that there are now so many firms engaged in the work compared with the number when this journal was started two years ago, speaks, we think, of the rapidly increasing popularity of this form of construction in our islands. Although the increasing number of specialist firms must necessarily mean an increase of the industrial competition between the various parties concerned, it also implies that the demand has become a much greater one, and, above all that the field for reinforced concrete in this country is now being recognised as a wide one. During the last two years it has been the efforts of this journal to independently propagate the subject of reinforced concrete—independently inasmuch as we have pointed to the advantages as well as to certain disadvantages in this class of work. The results of putting the subject before one of the most influential groups of technical readers that any specialist journal can pride itself of—influential inasmuch as the choice of new work is in the hands of such readers—has been that our remarks are read with confidence, and something far more substantial is done towards the popularisation of the subject than if we limited ourselves to the laudatory side alone.

But we are convinced that the whole question of reinforced concrete is still in its infancy, that the number of systems will be rapidly increased, and that with their increase the idea among engineers that they might be playing into the hands of monopolists will disappear, to the advantage of the industry generally. Further, many who are desirous of specifying reinforced concrete work will soon commence to prepare their own detailed drawings of what they require, in a clearer way than heretofore. The fact of the engineer and architect getting into the habit of specifying their work more clearly should materially assist in the development of the subject.

For the building owner, and for the building owner particularly of plain and straightforward constructions, the economical advantages for using reinforced concrete are great. The actual monetary saving in capital outlay, and the saving in maintenance expenses are material, whilst the substantiality and safety of the building are frequently enhanced. For new civil engineering work, the economy obtainable is, at times, almost phenomenal, and here again the question of maintenance expenses is very substantial.

When a new form of construction with such advantages in economical aspects enters the field, if properly executed and carefully supervised, it simply cannot help making its way, and even in countries like ours, where innovations are not welcomed with enthusiasm, the saying that we are but a "Nation of Shopkeepers" will always carry the point, for where money is to be saved, the most conservative building owner soon gives way, whilst his professional adviser should only be too happy to have an opportunity of saving his client money if it can be done without incurring any unnecessary risk.

In a future article we propose dealing, in a similar way to this article, with what is termed "Civil Engineering," as distinct from the building construction side of reinforced concrete, *i.e.*, its application in bridges, piers, quays, etc.

REINFORCED CONCRETE BEAMS.

(1) Coignet System.—*Type A.*—In the beams designed on this system reinforcement is always applied in the upper part, or compression area, as well as the usual reinforcement in the lower part, or tension area.

In beams where the compression due to bending moment is greater than the amount that may safely come upon the concrete, the employment of compression reinforcement is absolutely necessary. The cross sectional area of steel in compression may then approach or even exceed that of the steel in tension. In beams where all the compression can safely be taken by the concrete, the cross sectional area of the steel in compression is considerably less than that of the steel in tension. The objects of the compression reinforcement under this condition are to provide for the fixation of the stirrups (described below) connecting the upper and lower longitudinal bars and to equalise the distribution of stresses in the concrete. It is claimed that the use of reinforcement not required for the resistance of compression does not involve the wasteful use of metal, because it permits reduction of the amount of concrete with corresponding reduction in the weight of the beam.

It is claimed, also, that this method of construction facilitates the preparation of beams in advance.

The stirrups, or members for resisting shearing stresses, are formed of thin steel rods bent to U-shape, the upper ends being passed over the bars in compression and secured by being twisted. The stirrups are always placed vertically, and are spaced at such intervals as will provide for the calculated distribution of shear in the length of the beam.

In structures where Coignet beams are applied in conjunction with floor slabs, having single or double reinforcement laid longitudinally and transversely, each beam is considered as having a T-section, a proportion of the floor slab on either side of the rib, or beam proper, being treated as part of the compression area. (See FLOORS.)

The main longitudinal reinforcement of Coignet beams is usually laid in straight bars; the same arrangement applies to floor slabs with double reinforcement; while in floor slabs with single reinforcement the bars are bent upwards near the supports so as to provide for the distribution of stresses due to continuous-beam action.

(1a.) — A new method of providing reinforcement against shear, recently introduced in connection with the Coignet system, consists in grouping together in the lower part of the beam a certain number of bars varying in length and with their ends bent upwards at an angle of 45 deg. The upper ends of the bars are then bent over the bars acting as compression reinforcement. Additional ties between the upper and lower bars are provided, if required, in the form previously described.

(2) Considère System.—For ordinary beams the tension reinforcement consists of round straight bars, some laid horizontally, and some bent up towards the ends as required to provide for the distribution of stresses due to continuous-beam action and for shearing stresses. Where required compression reinforcement is provided near the top surface of the concrete by spiral coils of steel rounds of varying sizes and diameters. Additional shear reinforcement is sometimes provided in the form of thin steel rods passed around the tension and compression members at such distances apart as may be desirable. Sometimes the concrete in compression near the supports of continuous beams is reinforced by spiral coils of round steel rods laid horizontally or nearly so. By this arrangement the beams can be constructed of uniform depth throughout.

Slabs used in conjunction with beams are reinforced by round bars, laid from beam to beam, bent up on either side of the supports and carried over them, and by other round bars laid at right angles to the first series.

For large girders and trusses, such as are employed in bridge work, and may sometimes be required in buildings, Considère adopts forms of braced construction wherein the compression members are reinforced with longitudinal bars and spiral coils, and the tension members are reinforced in the manner described above.

The advantages claimed for spiral reinforcement are stated under the headings Columns and Piles (*q.v.*).

(3) Hennebique System —Beams on this system include tension, shear, and sometimes compression, reinforcement. The tension bars are of two kinds: (*a*) straight bars parallel to the lower face of the concrete, and (*b*) bars in the same vertical plane, but bent upwards towards and carried over the supports of the beam so as to afford resistance to stresses distributed in the manner due to continuous-beam action.

The shear reinforcement consists of stirrups formed of steel strips of suitable gauge and width bent to U-shape and the upper ends bent out so as to afford secure anchorage in the concrete. The stirrups are always placed vertically, and are spaced in accordance with the distribution of shearing stress in the length of the beam.

An improvement, recently introduced in connection with this system, consists of a stirrup formed with a kink, which has the effect of gripping the bar inserted at the lower end of the U. It is claimed that accidental displacement of the stirrups during the deposition of concrete is thereby obviated.

In beams where the compressive stresses are so great proportionately to the available cross sectional area of concrete as to necessitate reinforcement in the upper part of a beam, straight bars are introduced, and inverted stirrups are applied extending down nearly to the bottom of the concrete.

It is claimed that the bent bars taken in connection with the straight bars and the stirrups constitute a truss akin to a polygonal braced girder.

Hennebique floor slabs are of similar design, except that reinforcement is disposed both longitudinally and transversely. (See Floors.)

When beams and slabs are applied in conjunction, the beams are considered as having a T-section, and are spaced apart at such intervals that half the width of the floor slab on either side is regarded as acting with the ribs, or beams proper.

Besides the design of rectangular four-sided and T-beams, Mr. L. G. Mouchel has utilised the main principles of the Hennebique patent in the construction of arched beams and latticed girders of long span. Members of these types, embodying some original features, represent what is termed Mouchel-Hennebique practice.

(4) "Improved Construction" System.—Hollow concrete beams, reinforced with straight round steel bars, two at the top and two at the bottom, and tie bars each with a straight portion along the middle third of the beam and two diagonal portions bent up and connected with the ends of the straight compression bars. The three series of bars with the concrete constitute a kind of polygonal truss.

The main tension and compression bars are tied transversely by rods bent around each bar and wound around the series of four bars forming coils with the pitch of 2 in. Two other tension bars are placed outside the two main tension bars.

For the manner in which these beams are employed, see Floors.

(5) Indented Steel Bar System.—Bars of this type are made of steel with a high elastic limit. They are square in cross section, and have indentations and projections alternately on their four sides.

It is claimed by the patentees that owing to the high elastic limit of the steel a higher working stress is permissible than should be used for mild steel bars, so that proportionately less metal is required, and that owing to the mechanical bond constituted by the indentations the bars are not liable to slip in the concrete.

In beams designed by the patentees the bars are applied in the usual manner for resisting tension, and where necessary compression, in the concrete.

For the resistance of shearing stress the tension bars are bent up at the ends, the straight portion of each bar constituting tension reinforcement, and the bent portions forming diagonal reinforcement against shear towards the supports. In the case of continuous beams the bars are of length sufficient to permit them to be continued along the upper portion of the beam across the supports.

Floor slabs are reinforced in generally similar fashion, and beams used in conjunction with slabs are calculated as T-shaped beams. (see Floors.)

(6) Johnson System.—The distinctive feature of this system is a form of steel wire lattice with square or oblong meshes. It is supplied with the greatest strength parallel to either the length or the width of the sheets, and is made of extra strength in certain parts as may be required.

For beam reinforcement the lattice is made in the form of troughs with tension rods along the bottom. The lattice in the sides of the trough constitutes shear reinforcement, and additional wires are incorporated if necessary.

In the case of beams carrying moderate loads, the reinforcement is used with square or oblong meshes, but for heavy loads the lattice is made with diamond meshes, so that the strands of the shear reinforcement shall be normal to the diagonal planes of rupture.

Floor slabs are reinforced by sheets of the lattice passing over the beams near the top surface of the concrete and arranged so that the cross section of the reinforcement presents a curve akin to that of the diagram of bending moments for uniformly distributed loading. (See FLOORS.)

The advantages claimed for this system are that the lattice forms an almost perfect tension bond, that the use of continuous sheets conduces to safety, and that the strands of the reinforcement are on direct lines of tension, thereby avoiding any tendency for the meshes to close up under strain as may occur in diamond-shaped meshes.

(7) ***Kahn System.*** — The trussed bar of this system, in which the shear and tension members are combined in one piece of metal, is laid in concrete beams after the wings have been bent upwards to an angle of 45 deg. Resistance to tension is then afforded by the main bar, and resistance to shear by the upward projecting wings.

For deep beams some of the bars are laid horizontally all the way near the bottom, and others slanting upwards from the same level towards the ends of the beams, with the object of distributing the shear reinforcement throughout the concrete and causing it to reach the very top of the beams.

For continuous beams short lengths of the bars are placed in an inverted position over the supports, such bars extending for a distance sufficient to provide for resistance to negative bending moments due to continuous-beam action. In such parts of the beams the shear members of the two series of bars are said to produce the effect of a latticed girder.

Floor slabs are reinforced on the Kahn system in a manner virtually the same as that adopted for beams. (See FLOORS.)

In cases where beams and slabs are used in conjunction, compression bars are employed in a reversed position at suitable distances apart over each beam, so as to provide for negative bending moments in both longitudinal and transverse directions and to bond the slabs with the beams.

The special advantages claimed for the Kahn system are that the failure of a structure reinforced by the trussed bars and tested to destruction occurs invariably by the breaking of the steel and then only after the steel has stretched from 20 per cent. to 25 per cent. of its entire length, and that sudden failure is improbable because, in virtue of the absolute connection between the wings and the main part of the bars, positive resistance is afforded to shear.

(8) ***Ridley-Cammell System.*** — The characteristic of this system is dovetail corrugated steel sheeting, applied as reinforcement in beams by forming troughs, with angle bars bolted or riveted at the bottom corners, and angle or other bars bolted to the top edges, the sheeting being bent over to complete the connections.

Floor slabs are reinforced with horizontal sheets of the corrugated metal. (See FLOORS.)

Among the advantages claimed by the patentees are that moulds and centring are rendered unnecessary, and that the advance preparation of the skeleton reinforcement renders unnecessary skilled labour and reduces supervision to a minimum.

(9) ***Wells System.*** — At first sight the sections of a beam on this system may appear to be identical with those of a Hennebique beam.

In point of fact, however, the system embodies distinctive features represented by the form of the main reinforcing bars, the manner in which these bars are applied, and the construction of the shear members.

A Wells beam includes straight and bent-up bars as tension reinforcement for ordinary beam and continuous-beam action; straight bars, where required, for compression reinforcement; and vertical stirrups, spaced at varying intervals apart, as shear reinforcement.

The tension reinforcement consists of specially rolled twin bars joined by a short web making a cross section somewhat resembling that of a double bull-headed rail. In beams where several bars are necessary, the bars are placed on edge in order to avoid increase of the beam width.

The shear members are termed *hangers* where used to connect bars of the upper and lower reinforcement or when attached to the tension bars and terminating in the concrete near the top of the beam. They are termed *bonders* when passing from the concrete in compression down to about the middle of the beam.

Table 1.—Summary of the Chief Characteristics of various Systems of Reinforced Concrete Beam Construction adopted in Great Britain.

No.	Name of System.	Form of Tension Bars.	Form of Compression Bars.	Form of Shear Reinforcement.	Method of Fixing Shear Reinforcement.	Direction of Shear Reinforcement.
1	Coignet	Round straight bars	Round straight bars	Round rods bent to U-shape	Looped under tension bars and twisted above compression bars	Vertical
1A	Coignet	Round straight bars and round bars bent up near supports	Round straight bars	Bent-up ends of extra tension bars	Continuous with extra tension bars	Diagonal
2	Considère	Round straight bars and round bars bent up near supports	Round straight bars	(*a*) Bent up ends of extra tension bars, and (*b*) round rods lapped round the main tension and compression bars	(*a*) Continuous with extra tension bars and (*b*) bent round tension and compression bars	(*a*) Diagonal (*b*) Vertical
3	Hennebique	Round straight bars and round bars bent up near supports	Round straight bars	Steel strip bent to U-shape and made with spring clip	Sprung on to tension bars and bent over for anchorage in concrete	Vertical
4	Improved Construction	Round straight bars and round bars bent up near supports	Round straight bars	Round rods wound around the main tension and compression bars	Bent round tension and compression bars	Spiral
5	Indented	Corrugated square bars, bent up near supports	Corrugated square straight bars	Bent-up ends of tension bars	Continuous with tension bars	Diagonal
6	Johnson	Round straight bars woven with wire lattice	—	Trough of wire lattice with rectangular or with diamond mesh	Woven with tension bars	Vertical or diagonal strands, according to mesh used
7	Kabn	Square bars generally straight, sometimes bent up towards supports	Square straight bars	Wings attached to main part of tension and compression bars	Continuous with tension and compression bars	Diagonal.
8	Ridley-Cammell	Angle bars straight, and corrugated sheeting	Angle or other bars straight	Trough of corrugated sheeting	Riveted or bolted	Continuous plate
9	Wells	Twin round bars connected by short web	Round straight bars	Steel strip hangers and bonders	Bent round tension bars	Vertical
10	Williams	Rolled steel sections, straight	Rolled steel sections, straight	(a) Round bars (b) Rolled steel sections. (c) Spiral coils of steel wire sometimes used in addition	(a) Ends split for anchorage in concrete (b) Rivetted or bolted to tension and compression bars	(a) Vertical (b) Diagonal (c) Spiral

The hangers and bonders are steel straps about $1\frac{1}{2}$ in. wide by $\frac{1}{16}$ in. thick, which have been passed through an indenting mill giving a corrugated surface intended to increase the bond between the concrete and the metal. The straps are secured by being bent round the main reinforcing bars.

In main beams the web joining the twin bars is split, and one bar of each pair is bent up near each end to provide for the distribution of stresses due to continuous-beam action. The bars thus separated are connected by hangers bent round each member of the pair. This is done before the bars are hoisted into position, additional hangers being driven into the concrete as soon as it is laid and before it begins to set.

In some cases ordinary round bars are employed instead of the twin bars; in others ordinary round bars are necessary in addition to twin bars; and additional bars are introduced as required over the supports of continuous beams.

Floor slabs used in conjunction with beams of the Wells type are reinforced by thin rods placed longitudinally and transversely at suitable intervals apart. (See FLOORS.)

(10) Williams System.—Beams of this type are reinforced with small rolled steel I-sections placed near the lower surfaces of the concrete, and with vertical round bars for withstanding shear, these bars being split at the ends to afford secure anchorage. When required, rolled steel I-bars are also placed in the compression area of the beams. For beams of large size and span railway metals are used for reinforcement with diagonals of suitable section to take the tensile strains which would be set up in a lattice girder. These diagonals are mechanically attached to the top and bottom reinforcement to enable the steelwork to be self-supporting when lowered into the moulds.

In some cases steel wire applied in spiral coils of about 3-in. pitch is applied outside the other reinforcement.

Slabs used in conjunction with beams are reinforced with very small rolled steel joists laid in concrete at suitable intervals apart with hoop steel lacing alternately above and below them at right angles. (See FLOORS.)

It is claimed that this forms a series of trusses of great strength.

REINFORCED CONCRETE FLOORS.

(1) Armoured Tubular Flooring System.—Floors of this type include concrete webs, rebated for tubes, in lengths up to 30ft., reinforced with corrugated steel bars of special form; concrete tubes in 8-in. lengths, rebated to fit the webs; and a top layer of concrete.

The floor is built by placing the webs on their supports, dropping the tubes between them, and then spreading the upper layer of concrete.

It is claimed that this type of floor is considerably lighter than any other concrete or reinforced concrete floor, and that the use of centring is entirely obviated.

Classified by the British Fire Prevention Committee as a floor affording *full* protection against fire under the "Universal Standards."

(2) Chain Concrete System.—Floors constructed on this system comprise main and secondary beams, and floor slabs reinforced by round steel bars laid in one direction, all the bars being connected by McDowall's patent steel clips, each clip connecting three bars. By suitable application of the clips the two outer bars of each group of three bars also form the outer bars of two adjoining groups, and so all the bars in the width of beams and floor slabs are linked up to form a continuous sheet of chain network.

(3) Coignet System.—Main and secondary beams combined with slabs to form a monolithic floor system. (See BEAMS.)

Classified by the British Fire Prevention Committee as a floor affording *full* protection against fire under the "Universal Standards."

(4) Columbian System.—This embodies the use of special ribbed steel bars, suspended by steel stirrups over rolled steel joists, laid between main girders or resting upon walls. By using heavy ribbed bars of the same type ordinary rolled steel joists can be eliminated.

The ribbed bars are completely embedded in concrete, being placed so as to withstand tension.

Classified by the British Fire Prevention Committee as a floor affording *full* protection against fire under the " Universal Standards," and classified as " fire resisting " for New York under a similar standard.

(5) Dawnay System.—This system comprises two types of reinforced concrete floors.

(*a*) One embodies small rolled steel joists laid at intervals of 16 in. apart between larger joists, and embedded in concrete; and (*b*) in the other, square steel bars are laid between joists at intervals of 12 in. as tension reinforcement.

(6) Expanded Metal System.—In concrete floor construction expanded metal is applied in sheets, either carried over the top flanges of ordinary rolled steel joists or laid in sheets between the webs of the joists.

In the former case the sheets are curved to follow the line of tension in accordance with the diagram of bending moments, and in the latter additional sheets are required over the supports so as to provide for resistance to tension, due to continuous-beam action, in the upper part of the concrete.

The rolled steel joists are usually embedded in concrete either completely or leaving their lower flanges to be covered by expanded metal lathing and plaster.

Classified by the British Fire Prevention Committee as a floor affording *full* protection against fire under the " Universal Standards," and classified as " fire-resisting " for New York under a similar standard.

(7) Hennebique System.—Main and secondary beams combined with slabs to form a monolithic floor system. (See BEAMS.)

Classified as " fire resisting " for New York under a standard similar to the " Universal Standards."

(8) Hodkin-Jones System.—This consists in the reinforcement of concrete slabs with special bars having three corrugations in their width. By affording resistance to tension in the concrete these bars obviate the use of rolled steel joists. They are placed on edge, and are fixed in position either by being built into the walls or when resting upon steel girders by means of a specially pierced and bent plate slotted over the butting ends of the bars.

(9) Homan System.—(*a*) Round steel tension bars are passed through holes in the webs of rolled steel joists and embedded in concrete, forming slabs. The ends of the bars pass for a sufficient distance into adjoining panels to provide a bond.

It is claimed that in this manner any thrust upon the walls is prevented, and that spans up to 30 ft. are practicable without the use of main girders.

(*b*) Another form of Homan concrete floor construction embodies tension reinforcement in the form of T-bars with corrugated web.

It is claimed for this form of T-bar that the corrugated stem gives a firmer hold to the concrete and increases the lateral strength of the member; also that the weight of the metal is concentrated towards the flanges, where strength is most required.

(10) "Improved Construction" System.—Floors of this type are built up of hollow beams, reinforced as described under the heading BEAMS (*q.v.*), the sides of which are rebated in such manner that when two beams are placed side by side a V is formed near the lower surface and the sides present two rectangular grooves and two rectangular projections. A reinforced concrete " key " is moulded into the space thus left, joining up the beams to form a monolithic floor. The " keys " are reinforced with longitudinal round bars a short distance above and below the probable position of the neutral axis, and are connected by shear reinforcement consisting of round rods bent over the longitudinal bars.

(11) Indented Bar System.—Main and secondary beams combined with slabs to form a monolithic floor system. (See Beams.)

Classified by the British Fire Prevention Committee as a floor affording *full* protection against fire under the "Universal Standards," and classified as "fire resisting" for New York under a similar standard.

Table II.—Summary of the Chief Characteristics of various Systems of Reinforced Concrete Floor Construction adopted in Great Britain.

No.	Name of System	Form of Tension Reinforcement	Form of Compression Reinforcement	Form of Shear Reinforcement	Form of Concrete Filling	Construction of Secondary Beams
1	Armoured Tubular Flooring	Special corrugated straightbars	—	—	Cinder concrete tubes and top layer of mass concrete	—
2	Chain Concrete	Round bars straight	—	—	Mass Concrete	—
3	Coignet	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)
4	Columbian	Special ribbed straight bars	—	—	Mass concrete	(*a*) Rolled steel joists (*b*) Heavy ribbed bars
5	Dawnay	(*a*) Rolled steel joists (*b*) Square straight bars	—	—	Mass concrete	Rolled steel joists
6	Expanded Metal	Expanded metal sheets	—	—	Mass concrete	Rolled steel joists
7	Hennebique	As in Beams (q.v)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)
8	Hodkin-Jones	Special corrugated bars, straight	—	—	Mass concrete	—
9	Homan	(*a*) Round straight bars (*b*) Special corrugated **T**-bars	—	—	Mass concrete	Rolled steel joists
10	Improved Construction	Round straight bars	Round straight bars	Round straight bars	Reinforced concrete key between contiguous hollow beams	—
11	Indented Bar	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)
12	Johnson	Steel wire lattice	— As in Beams (q.v.)	—	Mass Concrete	(*a*) Rolled steel joists (*b*) As in Beams (q v)
13	Kahn	As in Beams (q.v)	As in Beams (q.v.)	As in Beams (q.v)	As in Beams (q.v.)	As in Beams (q.v.)
14	Kœnen	Round bars curved up toward supports	—	—	Mass concrete haunched at supports	Rolled steel joists
15	Lindsay	Round steel bars crossed above and below joists	—	Rolled steel joists	Mass Concrete	Rolled steel joists
16	Potter	Corrugated steel bars	—	—	Mass concrete	Rolled steel joists
17	Ridley-Cammell	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)	As in Beams (q.v.)
8	Somerville	(a) Round steel bars in slab blocks	Round steel bars in slab blocks	Round Steel bars in slab blocks	Hollow blocks	Rolled steel joists
		(b) Round steel bars in slab blocks. Kahn and round bars in beams	Round steel bars in slab blocks	Kahn bar wings	Hollow blocks	Reinforced concrete
19	Wells.	Round steel bars	Round steel bars	—	Mass Concrete	As in Beams (q.v.)
20	Wilkinson	Round bars straight and some bent up near supports	Round straight bars over supports	—	Mass Concrete part granite part brick and clinker	Either none or rolled steel joists

(12) Johnson System.—Rolled steel joists are generally used as supports for slabs, the joists being wholly or partly embedded in concrete and connected by arched or flat slabs reinforced with steel wire lattice. (See Beams.)

An alternative method of construction which has not been adopted to any great extent at present is to employ main and secondary beams of the type described under the heading BEAMS in conjunction with reinforced concrete slabs, thereby making a monolithic floor system.

(13) Kahn System.—As applied in Great Britain this system is used in main and secondary beams and slabs reinforced as described under BEAMS.

Classified as "fire resisting" for New York under a standard similar to the "Universal Standards."

(14) Kœnen System.—Concrete floor slabs, haunched near the supports, which consist of brick piers or steel joists. Reinforcement is provided in the form of round iron or steel bars laid as a catenary line in the middle portion of the span (*i.e.*, between the haunches of the slab), and curved thence gradually upward towards the supports, where the bars are anchored in suitable manner.

(15) Lindsay System.—The main and secondary beams consist of built-up girders and rolled steel joists embedded in concrete. The floor slabs are reinforced by round steel bars in pairs, the bars passing alternately over and under the joists and crossing at the middle of each panel, thereby forming trussed construction, which the patentees claim not merely supplies a tension bond to the concrete but also gives additional strength to the rolled steel joists. The further claim is made that the presence of the joists furnishes a proper amount of metal to resist shearing stresses near the bearings of long spans.

(16) Potter System.—Comprising monolithic concrete slabs, reinforced against tension by corrugated rods, applied in accordance with arrangements to suit varying architectural requirements, and with rolled steel joists where the distances between supports are over 12 ft.

(17) Ridley-Cammell System.—Main and secondary beams combined with slabs to form a monolithic floor system. (See BEAMS.)

(18) Somerville System.—There are two special forms of floor construction on this system.

In type *a*, the weight is carried by rolled steel joists, supporting on their lower flanges concrete hollow blocks reinforced with round steel bars, the blocks being flat at the bottom and curved at the top. The floor is finished by an upper layer of concrete.

In type *b*, reinforced concrete hollow blocks are supported by beams formed of concrete reinforced by a steel frame constructed of round and square rods so arranged as to take up the shearing and bending stresses, the floor being completed by a top layer of concrete. The whole, with the exception of the concrete blocks, being formed "in situ," a series of tee-beams is obtained, the top filling taking up the compressions.

(19) Wells System.—Main and secondary beams combined with slabs to form a monolithic floor system. (See BEAMS.)

(20) Wilkinson System.—Todd's patent platform floor construction, adopted in this system, requires no intermediate supports between the main walls or girders of a building. The floor consists of a slab formed of brick and clinker concrete from the bottom surface to within about 1 in. of the top surface, the upper layer being of Wilkinson's granite concrete. The slab is reinforced by longitudinal round steel bars, some laid straight for their entire length, and others bent up towards the supports, the ends of all the bars being bent over to afford secure anchorage in the concrete; transverse bars of the same cross sectional form are laid at intervals between the supports.

In the case of continuous slabs passing over one or more intermediate supports, additional bars are placed above each support with their hooked ends projecting downwards. These extra bars are intended to give further resistance to tension occasioned by continuous-beam action in the upper part of the slab.

REINFORCED CONCRETE COLUMNS.

(1) Coignet System.—Columns on this system are made either cylindrical or square in cross section. The longitudinal reinforcement consists of ordinary round steel bars, usually four in number, and the lateral reinforcement is constituted by a spiral winding of steel rods in coils spaced from 3 in. to 4 in. apart, the overlapping ends being bound with annealed wire. The chief advantage claimed by the patentee is the great resistance offered by his columns to side thrust.

(2) Considère System.—Columns on this system are made either cylindrical, octagonal, or square, in cross section, the reinforcement consisting of a spiral winding of steel rods usually from 2½ in. to 3 in. pitch, and of longitudinal bars usually 4 to 6 in. apart.

The special advantages claimed by M. Considère for spiral reinforcement are (1) that it greatly augments the load-carrying capacity of concrete columns while reducing the proportion of steel required and the cost of construction, and (2) that the moulds can be removed in a very short time after the columns have been built, as the spirally hooped core cannot bulge outwards.

Table III.—Summary of the Chief Characteristics of various Systems of Reinforced Concrete Column Construction adopted in Great Britain.

No.	Name of System.	Form of Longitudinal Reinforcement.	Form of Transverse Reinforcement.	Method of Fixing Transverse Reinforcement.	Direction of Transverse Reinforcement.
1	Coignet	Round bars straight	Round rods in spiral coils	Secured at ends by wire	Spiral
2	Considère	Round bars straight	Round rods in spiral coils	Ends of coils bent inwards	Spiral
3	Hennebique	Round bars straight	Wire links	Looped over longitudinal bars and anchored into concrete	Horizontal
4	Indented	Corrugated square bars, straight	Wire lateral ties	Wrapped-round longitudinal bars	Horizontal
5	Johnson	Round rods woven into lattice	Wire lattice rectangular mesh	Continuous mesh	Horizontal
6	Kahn	Square bars straight	Wings attached to main part of longitudinal bars	Continuous with longitudinal bars	Diagonal
7	Ridley-Cammell	Angle, flat, or half-round bars, straight	Dovetail corrugated sheeting	Riveted, bolted, or wired,	Continuous plate
8	Wells	Round bars straight	Round rods	Bent around longitudinal bars and hooked	Horizontal

(3) Hennebique System.—Columns on this system are generally either square or oblong in cross section, the reinforcement comprising four or more longitudinal bars transversely tied at short intervals apart by wire links in sets of four or more so that each set forms a continuous lateral tie at the level where the links are applied. The links are made of stout wire with the ends twisted, the projecting parts so formed being placed towards the interior of the column where they constitute anchorage, helping to resist outward thrust.

The transverse reinforcement of Hennebique columns formerly consisted of iron or steel plates with a hole at each end so as to enable the plates to be applied on the longitudinal bars in sets of four or more. These plate ties have now been superseded by wire links which, the patentee claims, produce an effect akin to that obtained by spiral winding.

(4) Indented Bar System.—Columns designed by the Indented Steel Bar Co. are of cylindrical, square, or oblong cross-section, as may be preferred, the reinforcement consisting of four or more longitudinal bars wrapped with soft iron wire forming lateral ties at short intervals apart.

(5) **Johnson System.**—This system has recently been adapted to column construction by preparing lengths of wire-lattice reinforcement comprising spiral coils with vertical rods woven in. The skeletons thus formed are made either for cylindrical or for square columns, the patentees claiming that they obviate the difficulty of keeping the spirals in position during moulding and tamping.

(6) **Kahn System.** — In column construction with Kahn trussed bars it is absolutely essential that the wings, used as shear reinforcement in beams, be bent at an angle of 45 deg. with the main members, that they extend entirely across the column, and the concrete be tamped in layers not exceeding 12 in. in depth to insure the absence of voids.

For columns designed to carry moderate loads no other reinforcement is required, but in cases where a relatively large proportion of longitudinal reinforcement becomes necessary, plain bars are sometimes employed in addition to the trussed bars so as to avoid an unnecessary and inconveniently large number of diagonals.

(7) **Ridley-Cammell System.**—Columns on this system are formed with reinforcement consisting of either angle, or of flat, or half-round bars placed vertically in pairs, and secured to dovetail-corrugated steel sheets forming a cage.

The makers claim that their columns are rigid and easy to build, and that the concrete is kept from breaking away at the corners, thereby preventing exposure of the reinforcement.

(*8*) **Wells System.** — Columns on this system are usually of rectangular cross-section reinforced with four or more longitudinal round steel bars, connected transversely at short intervals apart by ties formed of round steel rods passing entirely around the main bars and the ends formed with a hook-and-eye joint. Where more than four longitudinal bars are used additional transverse ties are applied with their ends bent so as to engage the main reinforcement.

REINFORCED CONCRETE WALLS AND PARTITIONS.

(*1*) **Coignet System.**—Walls of buildings are usually formed of columns, beams, and panels, all of reinforced concrete, or with brickwork panels.

The reinforcement of concrete wall panels consists of round steel bars disposed vertically and horizontally, forming a rectangular network. Shear reinforcement is used when required similar to that in floor slabs. (See Beams and Floors.)

Retaining walls are built with vertical or inclined panels strengthened by counterforts and founded on continuous footings, the whole being monolithic, and reinforced in the manner described under the headings Beams and Floors.

(*2*) **Expanded Metal System.**—Solid partition walls are formed with steel bars, provided with hooks and straining screws, clipped upon the rolled steel joists of the floors above and below the walls. The straining rods are placed at intervals of 12 in. apart, and sheets of expanded metal are wired to them. The sheets are covered on both sides with cement mortar. Angle or channel bars, or gas pipes, are sometimes used instead of round straining rods.

Hollow partition walls are formed on studs of steel angle bars connected by distance straps and on which sheets of expanded metal are secured as a basis for the two coats of cement mortar constituting the wall surfaces.

Walls of stronger types than those described above are constructed by building panels of concrete, reinforced with sheets of expanded metal, near each or one surface only as necessitated by prevailing conditions, between steel columns and beams embedded in concrete.

Retaining walls on the same system consist of vertical or inclined slabs reinforced with expanded metal sheets near each or one surface only, and strengthened at intervals by counterforts, also reinforced with expanded metal sheets. The walls and counterforts are founded on continuous concrete footings reinforced with expanded metal, the whole being of monolithic construction.

(*3*) ***Hennebique System.***—Walls of buildings are usually formed of columns, beams, and panels, all of reinforced concrete, or with brickwork panels.

The reinforcement of concrete panels consists of round steel bars disposed vertically and horizontally and of U-shaped stirrups, as employed in Beams *and* Floors (*q.v.*).

In walls where pressure may be exerted against either face, two series of rods are applied, with stirrups anchored into the concrete at the opposite face of the wall.

In walls where pressure can only be exerted against one side, one series of reinforcement is applied, with stirrups as before.

Retaining walls consist of vertical or inclined slabs, strengthened by counterforts at intervals, and a continuous foundation slab, the whole being of monolithic construction and reinforced in a manner generally resembling that described under the headings Beams and Floors.

Table IV.—Summary of the Chief Characteristics of various Systems of Reinforced Concrete Partition and Wall Construction adopted in Great Britain.

No.	Name of System	Kind of Wall	Form of Tension and Compression Reinforcement	Form of Shear Reinforcement	Method of Fixing Shear Reinforcement	Form of Studs or Uprights
1	Coignet	Wall panels Retaining Walls	As in Floors (q.v.)	As in Floors (q.v.)	As in Floors (q.v.)	Reinforced Concrete
2	Expanded Metal	Partitions Walls Retaining walls	Expanded metal Expanded metal Expanded metal	— —	— —	Round or other bars Round or other bars
3	Hennebique	Wall panels Retaining walls	As in Floors (q.v.) As in Floors (q.v.)	As in Floors (q.v.) As in Floors (q.v.)	As in Floors (q.v.) As in Floors (q.v.)	Reinforced Concrete Reinforced Concrete
4	Indented Bar	Wall panels Retaining walls	As in Floors (q.v.) As in Floors (q.v.)	As in Floors (q.v.) As in Floors (q.v.)	As in Floors (q.v.) As in Floors (q.v.)	Reinforced Concrete Reinforced Concrete
5	Johnson	Partitions and walls	Wire lattice	—	—	Angle bars or flat plate
6	Kahn	Walls Retaining walls	As in Floors (q.v.) As in Floors (q.v.)	As in Floors (q.v.) As in Floors (q.v.)	As in Floors (q.v.) As in Floors (q.v.)	Reinforced Concrete Reinforced Concrete
7	Ridley-Cammell	Partitions and walls	Dovetail corrugated sheets	—	—	Round or other bars
8	Wells	Wall panels	As in Floors (q.v.)	As in Floors (q.v.)	As in Floors (q.v.)	Reinforced Concrete

(*4*) ***Indented Bar System.***—Walls of buildings are usually formed of columns, beams, and panels, all of reinforced concrete, or with brickwork panels.

The reinforcement of concrete panels consists of indented bars placed vertically and horizontally.

Retaining walls are treated either as vertical cantilevers or as slabs between counterforts, the reinforcement consisting of indented bars laid in the direction required by the main stress. If necessary a secondary system of bars is added for preventing the formation of temperature cracks.

(*5*) ***Johnson System.***— Hollow partitions are built with studs of light angle bars connected by flat distance straps, or by thin plates bent to channel form, or by thin flat plates. On each side of the studs Johnson's galvanised "fireproof" lathing is wired or clipped, the reinforcement being covered with cement mortar.

Solid partitions are built with studs consisting of round steel bars, channel bars, or small I-bars. Crittal patent lathing is used as reinforcement for the cement mortar covering.

Hollow and solid walls are formed in a similar way, with stronger studs and reinforcement.

(*6*) ***Kahn System.***—Walls for buildings consist of columns, beams, and panels, all of reinforced concrete, or panels of brickwork. The reinforcement of concrete panels consists of trussed bars placed vertically and horizontally, with the wings projecting from side to side of the concrete.

Retaining walls consist essentially of beams, slabs, and counterforts, reinforced with Kahn bars, applied as in floor construction.

For very high retaining walls an intermediate slab or shelf is employed, supported by a lower series of rectangular counterforts, and carrying an upper series of triangular counterforts. This arrangement reduces the problem of design to one involving two walls, one above the other.

A special advantage claimed for the Kahn bar in counterforts is its ability to pull in a large block of concrete by means of the shear members, thereby enabling the entire mass of concrete to be utilised.

(*7*) ***Ridley-Cammell System.***—Dovetail corrugated sheeting is employed as reinforcement for cement mortar applied on each side, forming a solid partition wall. Bars of suitable section are used as studs where necessary.

(*8*) ***Wells System.***—Walls f buildings are usually formed of columns, beams, and panels, all of reinforced concrete, or with brickwork panels. The reinforcement of concrete panels consists of round steel bars disposed vertically and horizontally, forming a rectangular network on both faces of the panel.

REINFORCED CONCRETE CHIMNEYS.

(*1*) ***Weber System.***—The principle of design consists of two distinct parts—a combined lower double shell portion, with a single shell portion above. The height of the double shell portion is entirely dependent upon the purpose of the chimney, also nature and heat of the chimney gases, etc., and location of the smoke entrance.

The outer shell of the double portion sustains the vertical loads, and the bending forces caused by wind pressure, etc., whilst the inner shell is to protect the outer or carrying shell from the effects of high temperature or sudden cooling, the combination of these two shells increasing the draught efficiency of the chimney very materially. At the top of the inner shell an expansion joint is provided in order to allow for free expansion of this shell. Between these two shells there is a circular air-space insulation.

All shells are absolutely circular and of even thickness all round, assuring even expansion and contraction, thus preventing cracks.

The reinforcement comprises a network of bars for the chimney proper, and a second network of bars for an outer shell extending to a suitable proportion of the height.

The first network has vertical bars taking up all bending stresses and continued downward into the foundations, where they are bent to spread out over the base, thereby forming secure anchorage for the chimney shaft. These bars are overlapped 24 in. or more at the ends, and are encircled by steel rings about 18 in. apart vertically, taking up shearing and temperature stresses.

The second network has longitudinal bars disposed obliquely, and also bound by steel rings.

The foundation is reinforced by two layers of steel bars laid diagonal and parallel to the sides of the base.

REINFORCED CONCRETE PILES.

(*1*) ***"Armoured" System.***—The reinforcement consists of angle bars near the corners of a rectangular pile, connected at intervals by flat steel bands riveted on, and at more frequent intervals by diaphragms of steel wire in numerous folds or pleats, forming a series of springs. A pointed steel shoe is fitted at the lower end of the pile, and the head is bound with an outside strap.

(2) Coignet System.—The form of these piles is cylindrical, either solid or hollow, the reinforcement consisting of longitudinal round steel bars and a continuous spiral binding of steel wire. A pointed shoe is provided at the lower end of the pile, and at the head the spiral coils are spaced more closely than in the body, so as to afford greater resistance to the effect of blows received during the operation of driving.

(3) Considere System.—The form of pile generally adopted is octagonal, the reinforcement comprising a continuous spiral of round steel rods, and longitudinal rods equally spaced inside the spiral (usually eight in number), the pitch of the spiral usually ranging from about 1¼ in. near the head to 2 in. at the middle, again diminishing to 1½ in. at the foot, which is fitted with a steel shoe. The pile-head is cylindrical and bound outside for a distance of about 4 in. with steel coils of close pitch, the object being to enable the concrete to withstand the shock of driving without the use of a cap or dolly.

(4) Hennebique System (see also Mouchel System).—There are two types:—

Type a.—Foundation piles of square section reinforced by longitudinal round steel bars near the corners and by steel wire links in sets of four spaced at frequent intervals. The longitudinal and transverse reinforcement is similar to that in Hennebique columns (*q.v.*). The longitudinal bars are bent inwards at the foot and take bearing upon the inside of a steel driving shoe, secured in position by four straps whose ends are bent inwards and anchored into the concrete.

Table V.—Summary of the Chief Characteristics of various Systems of Reinforced Concrete Pile Construction adopted in Great Britain.

No.	Name of System.	Form of Longitudinal Reinforcement.	Form of Transverse Reinforcement.	Method of Fixing Transverse Reinforcement.	Direction of Transverse Reinforcement.
1	Armoured	Angle bars	Flat bars and folded wire diaphragms	Rivetted to Angle bars	Horizontal
2	Coignet	Round bars	Wire	Secured by wiring	Spiral
3	Considère	Round bars	Round rods	—	Spiral
4	Hennebique	Round bars	Wire links	Looped over longitudinal bars and anchored in concrete	Horizontal
5	Johnson	Round bars	Wire tires and lattice	Woven into a cage	Horizontal
6	Monchel	Round bars	Wire links and 4-arm diaphragm	Looped over longitudinal bars and anchored in concrete	Horizontal
7	Simplex	(*a*) —	—	—	—
		(*b*) Sheet steel tube	Sheet steel tube	—	—
		(*c*) Expanded metal	Expanded metal	Wired into cage form	Diagonal
		(*d*) Round bars	Round bar ties	Looped around longitudinal bars	Horizontal
8	Williams	Rolled steel joist	(*a*) Flat bars (*b*) Trussed construction sometimes added	(*a*) Bars hooped (*b*) Rivetted	(*a*) Horizontal (*b*) —

Type b.—Sheet piles of oblong cross section reinforced similarly to foundation piles, but made with an oblique chisel-edged toe, so that the piles can be driven one after another, each in close contact with its neighbour. Two sides of each pile are moulded with a semi-circular groove, two adjacent grooves forming a circular hole, which is filled up with a dowel of fine concrete, preventing the percolation of water through a row of the piles.

Driving is performed by the aid of a cast steel cap, filled with sand or sawdust, to distribute the force of the blows equally over the concrete.

(5) Johnson System.—A new form of pile construction, with four longitudinal round steel bars and steel wire lateral ties at intervals, the whole connected by steel wire lattice and forming a rectangular cage. Three of the longitudinal bars are passed through loops at the corners of the cage, leaving one side free to open as a lid. Concrete

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

JANUARY. 1908. VOL. II. No. 6.

A Bi-Monthly Journal for Engineers, Architects and Surveyors—Contractors and Builders—and all Workers in Cement, Concrete, Reinforced Concrete, and Constructional Steel.

CONTENTS.

Editorial Notes.

Reinforced Concrete Systems in Great Britain.

Reinforced Concrete Construction in the Rebuilding of San Francisco.

Historical Notes on the Invention of Portland Cement.

A Chocolate Factory in Reinforced Concrete.

Reinforced Concrete Sea Defences. Part I.—A Dutch Example.
By H. HUISMAN (Holland).

Tests with Reinforced Concrete Beams and Columns.
Summarised by CHAS. F. MARSH, M.Inst.C.E.

New Works in Concrete:—Reinforced Concrete Bridges and Viaducts; A Reinforced Concrete Retaining Wall.

New Uses for Concrete:—Reinforced Concrete Telegraph Poles; Reinforced Concrete in Mines, etc.

Memoranda. **Load Tests.**

Single Copies, 1s. nett. *Annual,* Post Free, *7s. 6d*

ANNOUNCEMENT.

THIS journal was founded with the object of meeting the demand for reliable technical and economic information regarding concrete, reinforced concrete, and constructional engineering generally.

The uses of concrete and steel are at present being accorded the closest possible attention throughout the world.

This journal continues to present a reliable digest of the world's latest information on concrete and constructional engineering as applicable to British and Colonial readers. It is intended to serve as a guide to what is being done at home and abroad, and will also serve as the medium for the expression of thought and opinion affected, presented by the ablest exponents on all questions connected with concrete and constructional engineering.

Nearing the third year, the reception of the first two volumes has been most encouraging, and the subscription list is not only extensive, but includes the names of prominent leaders of the professions concerned.

SOME SUBJECTS DEALT WITH IN Vol. I. & Vol. II. (Nos. 1 to 5)

The Advent of the Concrete Age ...	**LIEUT.-COL. J. WINN, R.E. (V. I. No. 1).**
Reinforced Concrete in the States ...	**CAPT. SEWELL, Corps of Engineers, U.S.A. (V. I. No. 2).**
Reinforced Concrete in France ...	**N. DE TEDESCO, Editor "Le Ciment" (V. I. No. 3).**
Reinforced Concrete in Germany ...	**O. KOHLMORGEN (V. I. No. 5).**
Reinforced Concrete in Italy ...	**O. N. DI MONTENEGRO, Bologna (V. I. No. 6).**
Reinforced Concrete in Switzerland ...	**PROFESSOR F. SCHULE, Zurich (V. II. No. 2).**
Reinforced Concrete in Austria ...	**Dr. LUDWIG HESS, Brunn (V. II. No. 4).**
Reinforced Concrete in Holland ...	**S. J. RUTGERS, C.E., Rotterdam (V. II. No. 5).**
Reinforced Concrete Piles ...	**A. T. WALMISLEY, M.Inst.C.E. (V. I. No. 2).**
Reinforced Concrete Water Mains ...	**R. H. WYRILL, M.Inst.C.E. (V. I. No. 3).**
Reinforced Concrete Bridges, Wharves and Quays	**W. NOBLE TWELVETREES, M.Inst.M.E. (V. I. No. 3 to V. II. No. 4).**
Reinforced Concrete Foundations ...	**CHARLES F. MARSH, M.Inst.C.E. (V. I. No. 1).**
Reinforced Concrete on the G.W.R. ...	**W. ARMSTRONG, M.Inst.C.E. (V. I. No. 2).**
Reinforced Concrete Railway Sleepers...	**G. H. KIMBALL, M.Am.Soc.C.E. (V. I. No. 4).**
Hollow Concrete Block Building ...	**S. B. NEWBERRY, Cleveland, U.S.A. (V. I. No. 2).**
The Laws of Proportioning Concrete...	**CHARLES F. MARSH, M.Inst.C.E. (V. II. No. 4).**
The Preservation of Iron and Steel ...	**B. H. THWAITE, C.E. (V. I. Nos. 1 & 2).**
Concrete as a Fire Resistant ...	**JAMES SHEPPARD, A.Inst.E.E. (V. II. Nos. 1 & 5).**
Reinforced Concrete and Fire Office Rules	**F. A. MACDONALD (V. II. No. 3).**
Forms for Concrete Construction ...	**SANFORD THOMPSON, M.Am.Soc.C.E. (V. II. No. 3).**

THE SETTING OF PORTLAND CEMENT

A Series of Articles by

CECIL H. DESCH, D.Sc., Ph.D. (V. I. Nos. 1, 2, 4).
E. CANDLOT, Paris (V. I. No. 3).
M. GARY, Berlin (V. I. Nos. 5 & 6).
D. B. BUTLER, A.Inst.C.E., F.C.S. (V. II. No. 1).
H. LE CHATELIER, Paris (V. II. No. 2).
R. C. CARPENTER, U.S.A. (V. II. No. 3).

And a Summary of the Question debated in the above by
BERTRAM BLOUNT, F.I.C. (V. II. No. 5).

Publishing Offices: 57 Moorgate Street, London, E.C.

Annual Subscription, 7s. 6d. (post free); Triennial, 21s. (post free).

PRESS OPINIONS.

"The Times."

"A periodical . . . which will meet an acknowledged want and will be welcomed by engineers and contractors. . . . The Journal, which is well illustrated and admirably printed, starts under excellent auspices."

"Daily Telegraph."

"It is a striking indication of the rapidity with which the use of concrete and steel in building and engineering is spreading, that . . . is founded. The first number contains a series of interesting articles by well known authorities."

"The Financial Times."

"A feature of the magazine is the admirable and profuse illustrations, which should lend additional value to the articles and enable even an untechnical reader to follow them with interest and pleasure. The number is excellently printed. Certainly it deserves success."

"Engineering."

" . . . . It should prove useful to an important section of the engineering world . . . The periodical is well printed . . . and the numerous illustrations are good."

"Builder."

"The journal deserves more than a passing notice as the pioneer journal, in this country on the application of concrete steel and reinforced concrete. . . . It has made an admirable start . . . we are sure it will have a most useful and successful career."

The Progress of Reinforced Concrete in Great Britain during 1906.
Report of the R.I.B.A. Committee on Reinforced Concrete.
British Patent Rights and Reinforced Concrete Piles.
Concrete Houses for the United States.
Constructional Lessons from San Francisco.
Steel and Concrete Buildings in Scotland.
Reinforced Concrete at Munich (The New "Tietz" Stores).
Steel Skeleton Construction and the London Building Acts.
Failures in Reinforced Concrete.
The New French Rules as to Reinforced Concrete.
Steel and Concrete at the Ritz Hotel, London.
The Concrete Domes at Westminster Cathedral.
Reinforced Concrete at the Engineering Conference, June, 1907.
The Revised British Standard Specification for Portland Cement.
Reinforced Concrete Reservoirs.
The Connecticut Avenue Concrete Bridge, U.S.A.
The Manila Cathedral.
Hollow Concrete Blocks and their Patents.
Fictitious Portland Cement.

The R.I.B.A. and Reinforced Concrete.—The Fire Resistance of Concrete.—Fictitious "Portland" Cement.—The Merchandise Act.—Safeguards against Freezing in Concrete Construction.—Reinforced Concrete Roofs in Egypt.—Reinforced Brickwork in Australasia.—Reinforced Concrete Bridges and Water Towers.—New York Rules on Reinforced Concrete.—Flow of Concrete under Pressure.—Fire Tests with Reinforced Concrete.—Rigid Shear Members *versus* Loose Stirrups in Reinforced Concrete.—International Standards for Reinforced Concrete.—New Uses for Concrete.—New Works in Concrete.—Reinforced Concrete Fence Posts.—Tensile Bending Tests.—Reinforced Concrete Gasholder Tank.—Safe Deposit Vaults at Milan.—Cement Masts.—Reinforced Concrete in Mines.—Reinforced Concrete Caissons.—A Concrete Safe.—Brooklands Motor Track Bridge.—Tangier Harbour.—Coal Silos in Reinforced Concrete — A Concrete Moist Closet.—Concrete for Repairs.—Wireless Telegraphy Poles.

Publishing Offices: 57 Moorgate Street, London, E.C.

Annual Subscription, 7s. 6d. (post free); Triennial, 21s. (post free).

CONCRETE & CONSTRUCTIONAL ENGINEERING

CONCRETE PUBLICATIONS, Ltd.

Publishing Office:
57 MOORGATE STREET, LONDON, E.C.

Telegraphic Address: "* London."**
Telephone No.: 3197 Central.

SUBSCRIBERS' ORDER FORM.

To

THE CONCRETE PUBLICATIONS, LTD.,

57, Moorgate Street, London, E.C.

Please add $\frac{\text{my}}{\text{our}}$ name to the List of Subscribers to:

"Concrete and Constructional Engineering."

$\frac{\text{I}}{\text{We}}$ require______ $\frac{\text{copy}}{\text{copies}}$ for **ONE YEAR,** subscription **7s. 6d.,** post free, per copy.

$\frac{\text{I}}{\text{We}}$ require______ $\frac{\text{copy}}{\text{copies}}$ for **THREE YEARS,** subscription **21s.,** post free, per copy.

Delivery to commence from date of order.

Signature______________________

PLEASE WRITE PLAINLY

Occupation______________________

____

Address

$\frac{\text{I}}{\text{We}}$ enclose $\frac{\text{Cheque}}{\text{P.O.O.}}$ for **£** : : ______________________

Date_______________190

All Subscriptions are payable with Order.

No.__________

The arrangement by which subscriptions can be booked for three years at a slight rebate is for the convenience of Subscriber and Publisher alike, saving the expense of correspondence and postage, time and trouble. Triennial subscribers will not be affected by any increase of price or change to more frequent issues.

The subscriptions include free postal delivery to any country in the Postal Union.

The foreign equivalents for 7s. 6d. accepted by the Publisher will be 9.50 fr., 7.75 marks, or 1.75 dols.

The foreign equivalents for 21s. accepted by the Publisher will be 26.50 fr., 21.50 marks, or 5.25 dols.

Remittances should be payable to the Company, cheques, etc., crossed "Martin's Bank."

All subscriptions continue from year to year unless cancelled in writing one month before expiry.

CUT HERE.

1908. I.

:: W. H. SMITH & SON ::
Printers, 95 Fetter Lane, E.C

is deposited with the reinforcement laid flat in a mould and with the lid of the cage open. When the mould has been filled to within about an inch from the top the cage lid is shut down and secured by passing the fourth longitudinal bar through the loops. Concreting is then completed.

(6) ***Mouchel System.***—The longitudinal and transverse reinforcement is similar to that in Hennebique piles (*q.v.*), but the main longitudinal bars are further connected at intervals by steel diaphragms with four arms, and a centre which serves the purpose of holding in place hollow tubes of concrete forming the core of the pile. The pile-head is solid and the transverse reinforcement is more closely spaced there than in the body so as to provide greater resistance to the effect of blows received during the operation of driving.

(7) ***Simplex System.***—These piles are constructed " in situ " by means of a hollow cylindrical steel driving form and special apparatus. They are made in four types :— (*a*), of plain concrete; (*b*), of concrete with an outer shell of sheet steel; (*c*), by moulding in advance a concrete pile which is introduced into the ground through the driving form, this method obviating any hammering on the concrete and consequent risk of shattering the pile; (*d*) of the foregoing types with any desired system of reinforcement.

Type b is only used in places where the piles have to be constructed in water or in water-bearing strata.

(8) ***Williams System.***—Piles on this system consist of concrete moulded around a rolled steel joist, sometimes strengthened by the addition of flat steel bars riveted at each side to the ends of the joists and bellied outwards towards the middle of the pile. Boiler tubes passed through holes in the web of the joist at suitable distances enable the piles to be handled by the aid of shackles when less than a week old. The transverse reinforcement consists of $\frac{3}{16}$ in. steel wire hoops at intervals of about 12 in. apart, except at the pile head, where they are only 2 in. apart.

The point of the pile is formed by cutting away the web of the rolled steel joist, bending the flanges together, and cutting the corners off. These piles are driven direct with a hard wood dolly, the heads being surrounded by four pieces of timber firmly bolted together with clamps.

REINFORCED CONCRETE PIPES AND CONDUITS.

(1) ***Bonna System.***—Reinforcement consists of longitudinals and a spiral coil, both formed of special ribbed bars resembling those of the Columbian floor system. The spiral coils are notched into the web of the longitudinal bars and tied by wire.

For pressures exceeding 50 ft. head of water the pipes are built upon an inner

Table VI.—Summary of the chief characteristics of various systems of Reinforced Concrete Pipe and Conduit Construction adopted in Great Britain,

No.	Name of System.	Form of Longitudinal Reinforcement.	Form of Transverse Reinforcement.	Method of Fixing Transverse Reinforcement.	Direction of Transverse Reinforcement.
1	Bonna	Special ribbed bars	Special ribbed bars	Notched and wired	Spiral
2	Coignet	Round bars	Round bars in hoops, wire or rods in spirals	—	Perpendicular and spiral
3	Ellis	—	Round bars	Welded	Perpendicular
4	Expanded Metal	Expanded metal	Expanded metal	Wired	Diagonal
5	Hennebique	Round bars	Round bars in hoops or spirals	—	Perpendicular or spiral
6	Indented Bar	Corrugated square bars	Corrugated square bars	Overlapped and embedded in concrete.	Perpendicular
7	Johnson	Round bars	Wire lattice		Perpendicular
8	Monier	Round bars	Round bars in hoops	Woven and hooked Wired	Perpendicular

tube of sheet steel at the ends of which are welded collars serving as reinforcement for the flanges by which the pipes are coupled. The inside of the tube is faced with concrete to protect it from the action of liquid.

(2) ***Coignet System.***—Reinforced with longitudinal bars and circular hoops, forming a network with rectangular meshes, and in addition with wires or rods wound helically about the network. When not moulded in continuous lengths the pipes are coupled by spigot and socket joints.

(3) ***Ellis System.***—Circular and elliptical pipes of Portland cement and Mountsorrel granite, the pipes being reinforced with ribs formed of round steel rods welded and worked into the concrete. The pipes are made in lengths ranging from 2 ft. to 3 ft. long, having ogee joints.

(4) ***Expanded Metal System.***—Reinforced by sheets of expanded metal bent to circular form, the edges overlapped and wired.

(5) ***Hennebique System.***—Reinforced with longitudinal bars and either spiral coils or circular hoops secured by wiring. Method of jointing pipes to suit individual requirements.

(6) ***Indented Bar System.***—Reinforced with longitudinal bars and circular hoops of indented bars forming a network with rectangular meshes. The ends of the hoops are overlapped and held by being embedded in the concrete. If the ends cannot be embedded to the length of 20 diameters they are bent and hooked together.

(7) ***Johnson System.***—Reinforcement consists of steel wire lattice bent to circular form and provided with a hook over each meeting wire. It is claimed that this method gives as much strength at the intersection as that possessed elsewhere by the sheet of lattice.

(8) ***Monier System.***—Reinforced with longitudinal and circumferential bars forming a single or a double network. The intersections are tied with wire, and collars are generally used for coupling purposes.

Concrete and Reinforced Concrete Construction in the Rebuilding of San Francisco.

From Notes compiled on the spot by
JOHN R. CAHILL.

The excellent results shown by concrete and reinforced concrete in the earthquake and conflagration of San Francisco has necessarily brought about a considerable demand for these materials for the reconstruction of that city.

We say "considerable demand" advisedly, for the actual number of buildings in which these materials are being employed, though by no means small, would have been greater if it had been possible to comply with the demand to the full extent.

Some of the reasons why it has not been possible to use reinforced concrete to the extent of the demand are given in the article, but the primary reason is not sufficently indicated. This reason was the unscrupulous methods of the brick and terra-cotta interests (both masters and men), which were employed to thwart the use of reinforced concrete in a manner characteristic of the very worst sides of American business and municipal life. Everything that could be done by bribery, corruption, threats and riot was done in the interests of the brick and terra-cotta industry.

That reinforced concrete should have successfully survived these attacks speaks well for its inherent good qualities and economy. Reinforced concrete is being used in over 100 important buildings in San Francisco, apart from its use on civil engineering works, and we may safely prophesy its almost universal use now that its application has become established in San Francisco, and the advantages are realised.

We present some few examples of works in which reinforced concrete is being employed in San Francisco and an article by one who has recently visited the city. We hope to again deal with works executed there at a later date, but in the meantime the examples shown will prove its application regardless of what those who decry reinforced concrete may erroneously state.—ED.

FERRY TOWER.
(Steel Frame, with reinforced concrete walls. "Indented" Bar System.)

San Francisco is now the scene of an interesting struggle for the recognition of the merits of reinforced concrete in building construction.

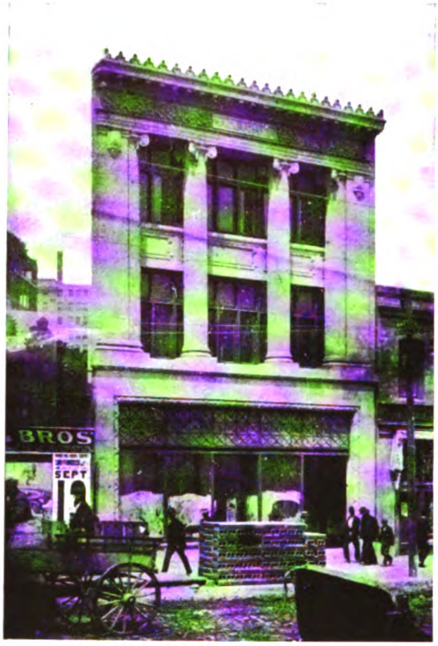
The fire was hardly over when the advocates of concrete construction began to urge that this type of building be used in the rehabilitation of the city. They immediately met with strong opposition from the members of the Brick and Steel Contractors' and Bricklayers' Labour Organisation, who instituted a vigorous campaign of disparagement, and finally attempted to prevent the use of concrete for structural members by influencing the City Board of Supervisors to forbid its use in that capacity. However, after listening to both sides of the question, the Supervisors decided to allow the construction of such buildings, but limited their height to 102 ft. above street level.

Since this decision the reinforced concrete industry has been steadily growing, despite the continual opposition of its rivals. Every accident that happened throughout the world in the erection of reinforced concrete structures, during the past year, was seized upon and used as an argument against the safety of such buildings. Incorrect rumours as to the great cost of such work were spread broadcast over the community, and sophistical arguments as to the advantage of steel frame buildings in point of time of construction were widely circulated.

It is needless to say that this opposition was successful to some extent. Probably there would have been many times as much reinforced concrete construction were it not for the extreme virulence of the attacks of the opposition, and had true facts concerning the situation been understood by the owners.

However, the public will have ample opportunities of judging of the merits of the type of construction during the next few months, when a great many buildings will have been completed and comparisons made between steel and wood-brick and concrete constructions. It is most probable that the result will be so favourable to the latter type that the concrete industry will receive a new impetus and the percentage of concrete buildings greatly increase.

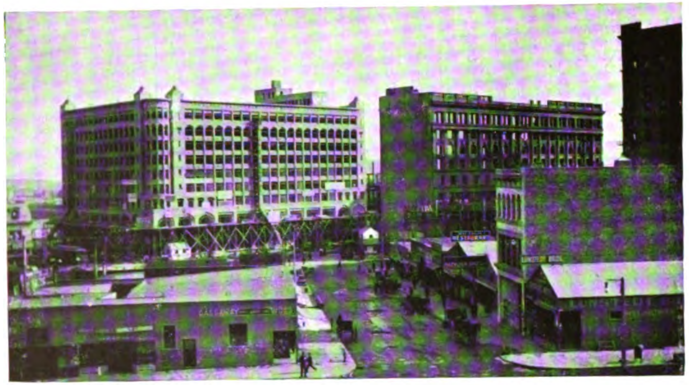
From this, the conclusion must not, however, be drawn that the building operations in concrete were slight. On the contrary, San Francisco is now the scene of immense activity in this direction. During one year, since the great fire, seventy-nine buildings having reinforced concrete frames and aggregating a total value of £1,400,000 (American cost) have been completed, or are in process of completion, despite the decided lull in business pending the adjustment of the labour troubles of the last few months. This, however, forms but a part of the reinforced concrete used. In addition to such buildings, reinforced concrete plays an important part in the construction of the steel-frame "Class A" buildings. The so-called "Class A" building, as defined in the municipal building regulations, is a steel-frame structure, carrying exterior



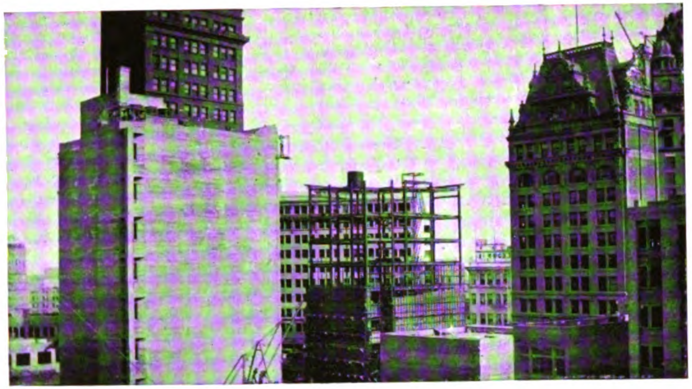
FREEMAN BUILDING.
Italian Renaissance treatment of reinforced concrete.

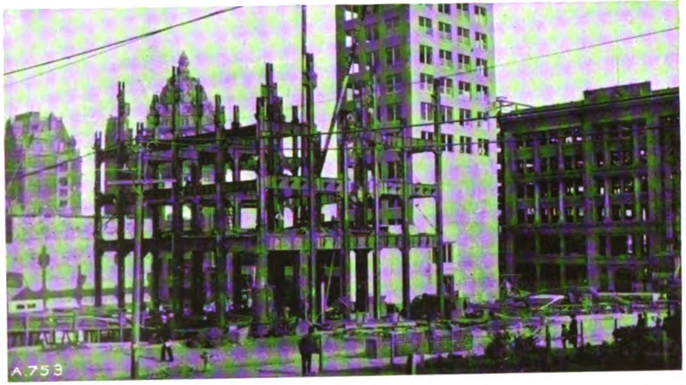
A typical reinforced concrete office and warehouse building in course of construction.

General View of buildings being constructed or under repair.

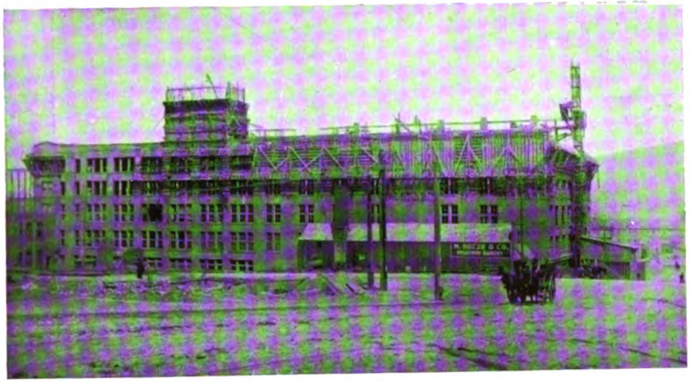


Examples of Steel Frame Buildings with reinforced concrete divisional walls and concrete floors.



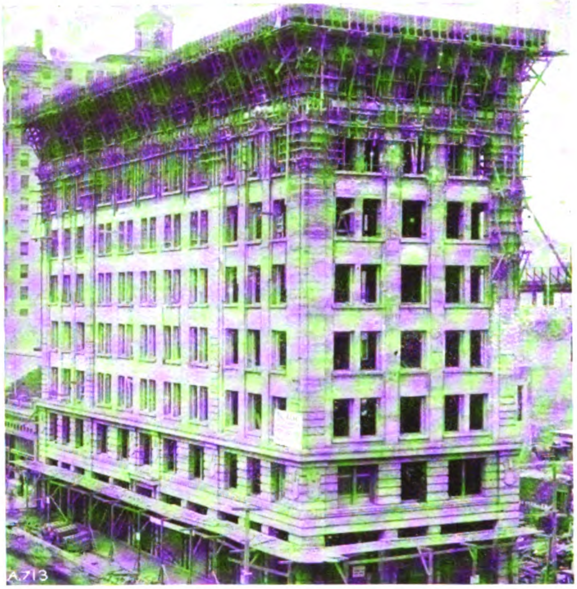


Steel Frame Building in course of Construction, showing Heavy Bracing (for earthquake shock) upon which concrete floor slabs will rest.



Typical reinforced concrete factory in course of construction (for The American Biscuit Co.).

CONCRETE AND REINFORCED CONCRETE IN SAN FRANCISCO.



BOYD BUILDING.
Erected in reinforced concrete with concrete roof, 8 storeys and basement, for which the Ferrolite Co. acted as architects, engineers and contractors, using "Indented" bars.

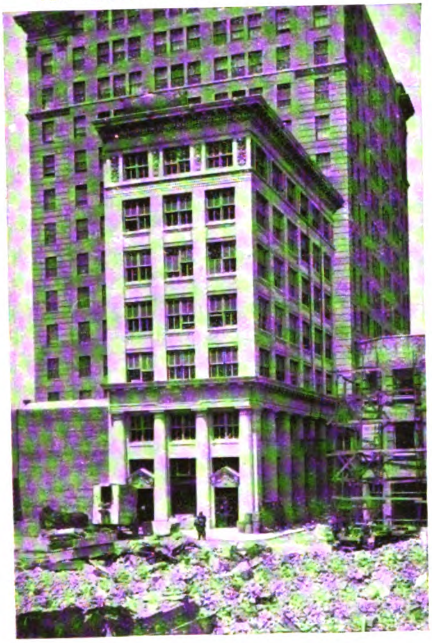
curtain walls on the steel frame and fire-proofed with terra-cotta, brick, or concrete. The earthquake and fire, however, having demonstrated that terra-cotta and brick are inferior to concrete for such purposes, most of the fire protection of the steel frames is being formed of concrete, and the brick or terra-cotta floor arches are being almost entirely superseded by concrete floor slabs. In addition, the side and rear walls of such structures are largely being made of reinforced concrete, and also curtain walls, owing to the saving in ground space and dead weight that may be effected and their acknowledged superiority over brick or masonry walls in case of earthquake shock.

For foundation and retaining wall work reinforced concrete is being widely used in all types of buildings. In electric railway road beds, sewer and dock construction, concrete is playing an important part, while designs are now being made for one of the electric power corporations for what will probably be the highest reinforced concrete dam in the world.

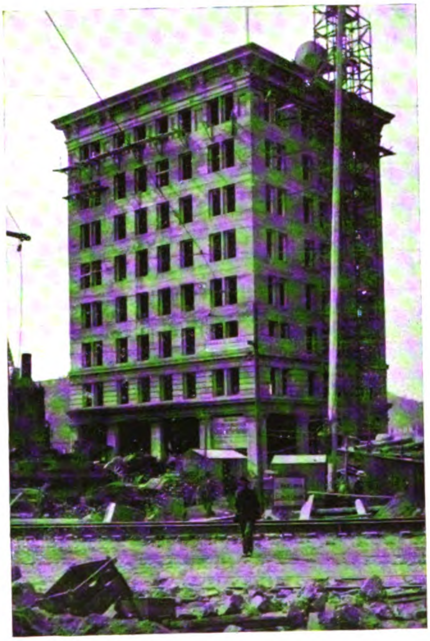
The fact that the building ordinances limit the height of all buildings to one and one-half times the width of the street brings about the extensive use of reinforced concrete in retaining wall work. In order to secure more room two or three sub-storeys are sometimes built below the street level. In one building of this kind, being designed for the Olympic Club, a retaining wall 60 ft. in height is being projected.

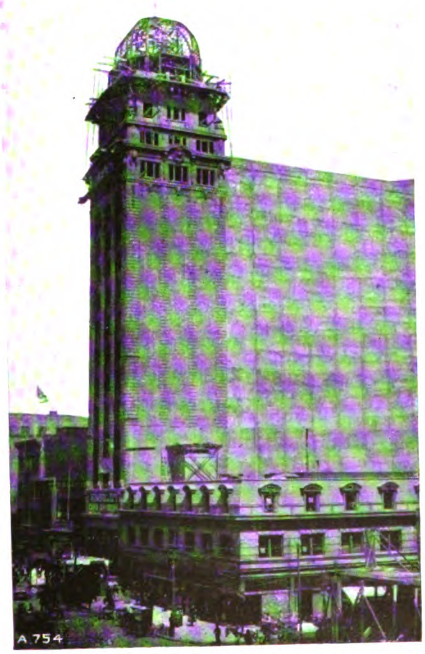
The purely reinforced concrete framed buildings fall into two main classes: those

Hopkins Building.
General View, erected in reinforced concrete throughout. (All ornamentation is in cement work.)

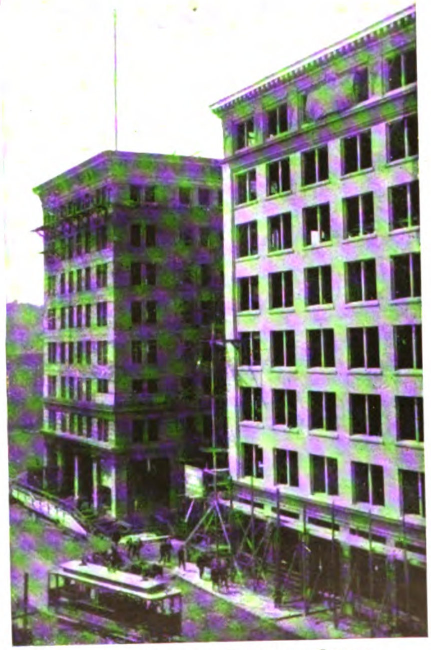


Boyd Building.
General View.





The Humboldt Bank.
Showing reinforced concrete blank wall.



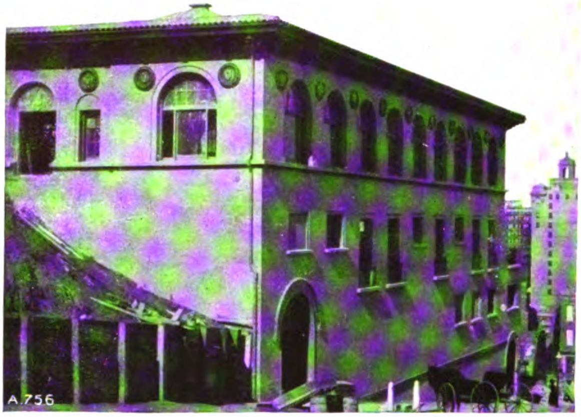
Two Reinforced Concrete Office Buildings

Concrete and Reinforced Concrete in San Francisco.

designed for heavy loads—warehouses, mills, factories, power houses, etc.—and those intended for light loads—apartment houses, banks, clubs, residences, hotels, and retail shops. About one-third are of the former class and two-thirds of the latter. The average height of all the reinforced concrete buildings is five storeys, there being one ten-storey, one nine-storey, and seven eight-storey structures.

About one-third of these concrete buildings are erected by construction firms that act as architect's engineers, and contractors on a percentage basis. Most of the remainder are designed by practising architects and built by construction companies on a percentage basis, the constructors generally furnishing the engineering designs.

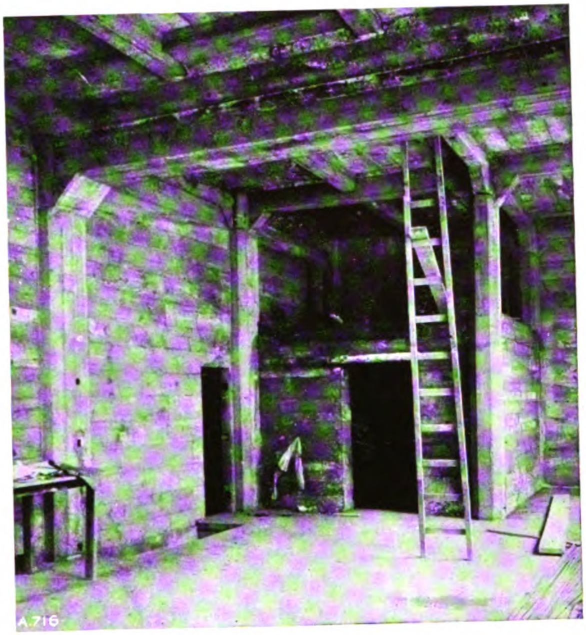
As regards the great fear of accidents during construction, that more than anything else has deterred the public from going more heavily into reinforced concrete construction; it is interesting to note that in more than a year of such work in San Francisco there has been no accident resulting in any death or serious injuries due to concrete failure, while in the erection of a steel structure a wreck occurred that cost the lives of two men and buried several others. This freedom from accident is restoring public confidence in the safety of the concrete type of construction.



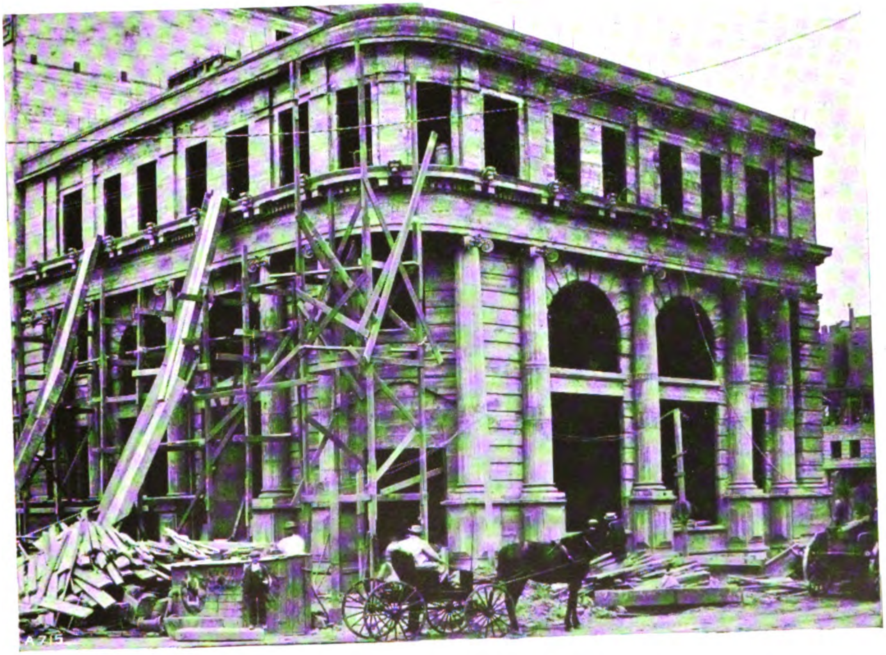
THE VIAVI BUILDING.
Spanish Renaissance treatment of reinforced concrete.

THE SCHAEFER BUILDING.
Comprising shops and tenements in reinforced concrete, with "Indented" bars.

The question as to the relative cost of a steel frame building, a reinforced concrete frame building, and a brick-wood building is the element that will bring the concrete construction more and more into popularity. Some lack of confidence in the new type of building has been due to the fact that directly after the fire many new contractors entered the field, without being thoroughly familiar with the labour union problem and the high cost of materials in San Francisco. This resulted in their preliminary figures being much too low, and on their subsequent increase the public became distrustful and prejudiced against the construction. This period now, however, has been passed, as sufficient cost data has been accumulated since the fire to enable a contractor to make out an intelligent estimate. Most of the contracts for building work in San Francisco since the fire have been let on a cost plus a percentage, or cost plus a premium system, owing to the contractors being loth to take the risks of change in a most uncertain labour and material market. As a result the advantage in point of economy of certain types of concrete structure could not be demonstrated to the satisfaction of the owners until the completion of the work.



THE PORTUGUESE AMERICAN BANK.
(Interior View.)



THE PORTUGUESE AMERICAN BANK.
Constructed in reinforced concrete with "Indented" bar reinforcements. Architect, C. H. Meussdorfer.
Engineers and contractors, Cotton Bros.

In point of time of erection the concrete buildings in competition with steel frame construction have an advantage in San Francisco not generally found in other localities. Most of the steel structural work is fabricated in eastern shops, and a period of from three to six months may elapse between the date of order and date of delivery of steel. On the other hand, there is but little delay in securing material for the reinforced concrete building. The work may be started from stock and finished from ordered material.

ECONOMY OF REINFORCED CONCRETE.

A review of the cost conditions in San Francisco will give an idea of the probable future growth of the concrete building. The type of structure in which concrete has the greatest advantage in point of cost is in warehouse or factory construction of two or three storeys in height having heavy floor loads. In such a building the structural members constitute the greatest part of the total cost, and the saving of the concrete beams and columns over those of steel makes a correspondingly great saving in the whole cost of the building. In such cases the concrete type may be from 15 to 30 per cent. cheaper than the steel type.

The writer made one comparative design for heavy warehouse construction when there were ideal conditions in favour of the concrete. The possibility of heavy local concentrated loads made an extra thick floor slab necessary, such that the concrete beams designed as T-beams were very much cheaper than corresponding steel beams. The heavy floor load made the ratio of cost of form-work to the cost of the beams unusually small, and made the difference in dead weight of the two types an unimportant item. The building was for the most part only two storeys in height, so that excessive steel in the basement concrete columns was not necessary in order to reduce size of columns to reasonable limits, and the columns were very long, causing steel sections to be increased to allow for flexure. The total cost of the concrete design figured about £45,000 (American cost), with the steel design at £60,000, a saving of 25 per cent. This figure did not include the fire-proofing of the steel, in which case the saving would run over 30 per cent.

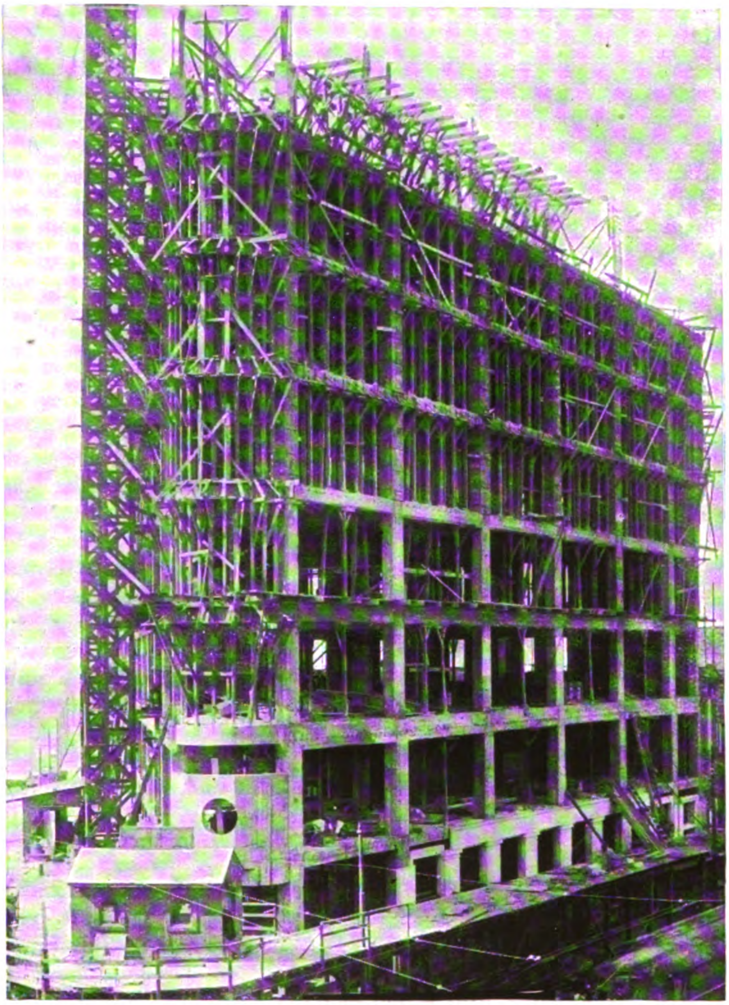
For office buildings and apartment houses the saving of concrete over steel construction in the total cost is not so great, inasmuch as the cost of the structural members is only about 20 per cent. of the entire cost. In such buildings the saving is generally from 15 to 20 per cent. of the cost of the structural members, or about 3 or 4 per cent. of the cost of the entire building.

For foundations reinforced concrete is generally found to be cheaper than steel grillage work, and owing to the difficulty of obtaining quick delivery of steel in San Francisco, is valued as a time-saver. Concrete is especially economical in its use for cantilever foundations. The writer made one comparative design for a ten-storey steel frame office building having a great many cantilever foundations which showed a saving of 20 per cent. in the use of reinforced concrete for the foundation. In the same building a saving in the steel-work was effected by using 6-in. exterior curtain walls of reinforced concrete. This reduced the weight necessary for the steel to carry and also effected a saving in the spandrel beams. The concrete wall was made self-supporting at each floor level by being made into a reinforced concrete beam resting on angle clips on the columns. Extra reinforcing bars were run from column to column. This allowed the use of very light steel framing between columns to take the local floor load and brace the columns.

The heavy warehouse and factory constructions vary from two to five storeys in height. The buildings for lighter loads, such as hotels, office buildings, etc., range from three to nine storeys in height. The building regulations limit the height of such buildings to 102 ft., but inasmuch as the bottom columns of a concrete building higher than this become either of enormous size, or become uneconomical through use of heavy excess steel reinforcements, this law does not have any ill effect on the concrete industry.

ARCHITECTURAL TREATMENT.

The architectural treatment of the exterior of the buildings has been one of the greatest difficulties encountered. Most of side and rear walls are made 6 in. in thickness, but for the façade the architect claims that such a thin section through the lack of depth revealed at the openings gives a suggestion of weakness. Hence the front walls of the buildings are made from 13 to 17 in. in thickness. Some of the exteriors have a veneer of tile, terra-cotta, or concrete blocks. Others are plastered with cement mortar, and tinted a light grey, white, or buff colour.



The First National Bank at Oakland (opposite San Francisco).
Constructed entirely in reinforced concrete with Kahn Bar reinforcements

In securing a fine and uniform colour and texture to the finish of cemented work, there is one construction company that has attained admirable results. They use cement ornaments cast in iron moulds, and treat all the cemented finish to a coat of light-coloured cement grout, which gives a very uniform surface and relieves any tendency towards a grey, gloomy effect. Probably the finest-looking concrete building erected in San Francisco is the one erected by this company for Mr. E. W. Hopkins. The building is a seven-storey office structure in the Italian Renaissance style. The intricate ornamentation in cast cement, massive yet delicately moulded cement pillars, and elaborate heavy cement cornice work form a very good example of what results can be obtained with this material. The texture of the castings is as fine as that of the ordinary sandstone building-stone. This building has not a piece of wood in it. The finish, doors, window frames, etc., are all of metal, and the window lights are all of wire-glass. One of the advantages that a large construction firm that does its own architectural designing has is well shown in this building and the Freeman building.

The forms for casting the massive concrete columns on the Hopkins building have been used again in producing columns for the Freeman building, resulting in saving of expense for both structures. Such a company is able to save a great deal in cost of form-work by adopting standard sizes and dimensions and using them as often as possible, admitting the use of forms several times without cutting.

CONCRETE AGGREGATES.

One of the difficulties the great demand for concrete brought with it was the resultant scarcity of crushed rock in the city. Under the auspices of the Structural Association of San Francisco a thorough study of the possibility of using crushed brickbats in concrete was made. Tests were made in the laboratories of the University of California, and all the engineering literature on the subject was investigated. The result of a thorough consideration of the subject was that the use of crushed brickbats, if properly washed and cleaned, was endorsed. This brought about the use of rock crushers on almost all of the large buildings. The fire had left thousands of tons of old brickbats lying apparently useless. These, along with injured building-stone, were hauled to the buildings and there crushed.

One of the most complete plants for handling and crushing the rock and brickbats, mixing the concrete and placing it, was in the factory building of the American Biscuit Co. Large rock crushers were used in crushing rock, a large saw-mill plant was installed for handling the cutting-up of form-work lumber, machine mixers were used, and the concrete was all placed by machinery. The building is reported to have cost £60,000.

NOTABLE EXAMPLES.

The most notable concrete building being erected is the Pacific building, a structure nine storeys high, having a ground plan of 175 ft. by 195 ft. The building will cost about £160,000. It is to be used as an office building. Its exterior for the first two storeys will be veneered with brown-tinted ceramic tile. Above the second storey the front will be faced with cream-coloured glazed terra-cotta.

The best example of the use of concrete in a steel frame building is the Humboldt Bank building, a seventeen-storey structure. The rear and side walls are of reinforced concrete, the light area walls being faced with white glazed tile. Part of the side

---

All values given refer to American cost, taking 5 dollars as equal to a sovereign.

The illustrations of the Ferry Tower, Boyd Building, Schaefer Building, and Portuguese American Bank have been put at our disposal by the Patent Indented Bar Co., Ltd., the illustration of the First National Bank at Oakland by Messrs. The Trussed Concrete Steel Co., Ltd., of London, and the other illustrations by the author.

walls and front elevation above the third floor are of reinforced concrete faced with moulded cement blocks. The walls are reinforced with corrugated bars. All the floor slabs are 4-in. concrete slabs reinforced with wire mesh. All fire-proofing is of concrete. The stairways are of concrete reinforced with bars. The building is fitted throughout with wire-glass windows, metal window frames, and a complete automatic sprinkler system. The building will cost over £100,000.

At the commencement of the concrete activity the general opinion was that the prevailing style of architecture in this type of construction would be an adaptation of the Spanish Mission style. The flat plastic surfaces of this type were said to be peculiarly adapted to the concrete finish, and the contrast of red tile with the buff or grey flat surface was said to be particularly effective. In spite of these prophecies there has been but one building of this type constructed. All others are the conventional designs for brick or stone applied to concrete. It is claimed, though, that the reason for this was a lack of time on the part of the designers for developing the new style. The largest designer in concrete in the city at present, however, is applying himself to this problem, and a more general change to the Mission style of architecture for concrete will soon be seen.

The Viavi building is the only building of this type. It is tinted a buff colour and roofed with red tile. It is a warehouse building, and from an architectural standpoint is the best designed warehouse of concrete in San Francisco.

The Boyd building is a good example of the ordinary reinforced concrete office building in San Francisco. It is an eight-storey building, 70 ft. by 62 ft., and will cost about £27,000. The cornices are of moulded cement, and poured in place. The foundation is of piles capped with reinforced concrete footings separated by reinforced concrete struts.

Of other examples illustrated, the Portuguese-American Bank and the Schaefer building should be specially mentioned.

We have also reproduced a photograph of the new First National Bank building, at Oakland, a city opposite San Francisco, where the earthquake also did considerable damage, and where reinforced concrete is being applied on a considerable scale.

INDEPENDENT OPINION ON REINFORCED CONCRETE.

Much has been written about the effect of fire and earthquake upon reinforced concrete, so but a brief mention of it need be made here. There were not many examples of this type of construction in the region at the time of the earthquake, but every one of the few that did go through the test stood it very well. The committee of the American Society of Civil Engineers, who made a report on this subject, recommend reinforced concrete as a good solution to the building problem in earthquake regions.

It is interesting to note that the president of Stanford University, in reporting upon rebuilding operations after receiving reports from a body of prominent engineers of San Francisco and the engineering faculty of the University, recommended the use of reinforced concrete. The engineering commission retained by the neighbouring city of San Jose to advise it as to proper building operations advised the use of either reinforced concrete or steel construction. The engineer employed by the State of California to advise it as to proper earthquake precautions also advised reinforced concrete or steel construction, so it is evident that, after careful study of earthquake conditions, reinforced concrete is considered proper construction to withstand severe shocks.

Some Historical Notes on the Invention of Portland Cement

The use of Portland Cement is so much under discussion at the present time, that a short historical retrospect on the advance and development of Portland Cement should, we believe, be interesting to the majority of our readers. We therefore present below, not only a reproduction of the original patent for Portland Cement of 1824, but also illustrate a group of original Portland Cement Kilns, and a pair of modern rotary Kilns.—ED

A Battery of old " Bottle " Kilns.

PORTLAND cement has now become of such supreme importance everywhere, in all forms of constructional work, that great interest is attached to the early history of this material. It is in response to a suggestion made by one of our subscribers that we publish the accompanying copy of the specification of Joseph Aspdin's original patent, No. 5022, of the year 1824.

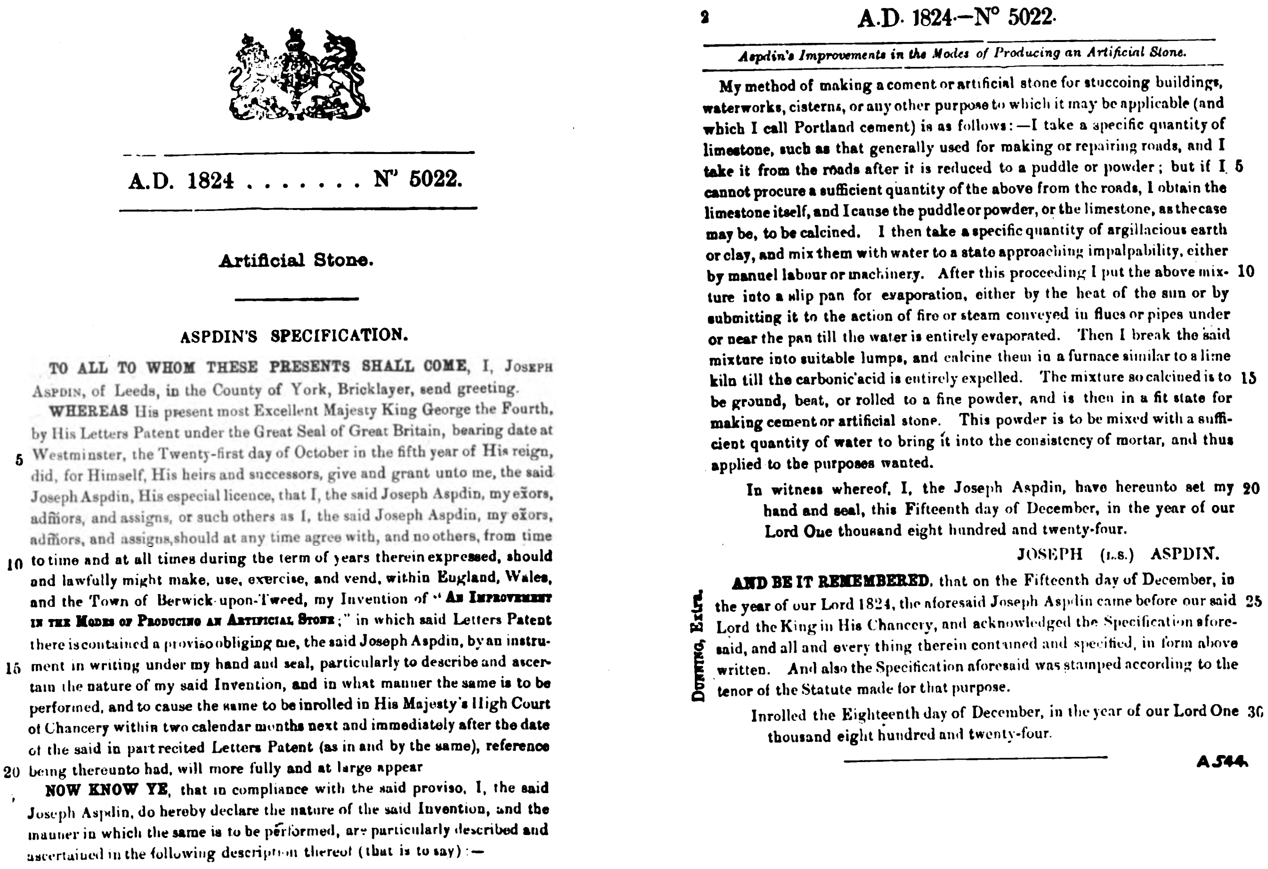
It is not surprising that the process of manufacture loosely described by him should differ as much from present methods as Portland cement now does from the cement to which he gave that name on account of its resembling Portland stone in colour and texture when worked up. Nevertheless, it is to this Yorkshire bricklayer, who established his works at Wakefield in the year 1825, that we are indebted for the discovery of Portland cement, and the vast improvements in its quality and in the methods by which it is produced bring the course of this industry over a period of three-quarters of a century, into line with the development of many other notable inventions and discoveries, such as that of the steam engine and steel.

Although Portland cement appears to have been chiefly used originally for stucco it is to be noted that Brunel, in the year 1828, employed a substantial quantity of it in the construction of the Thames Tunnel. He obtained it from Aspdin's factory at Wakefield, having previously satisfied himself that, notwithstanding its higher cost, it was immensely superior to the Roman cement which was then generally used.

The new material made but slow progress for many years, and it was not until William Aspdin, the inventor's son, established a factory on the Thames, first at Rotherhithe and shortly afterwards at Northfleet, that much advance was made.

In the year 1825 works had been established at Swanscombe by James Frost, for the manufacture of artificial cement, and in 1833 these works were acquired by Messrs. Francis and John Bazley White, whose successors, John Bazley White & Sons, later, when the merits of Portland cement had begun to attract general attention, became competitors of the younger Aspdin in the manufacture and sale of the new material.

From that small beginning these Swanscombe works have grown to their present size and importance. For over half a century Portland cement has been manufactured there in ever-increasing quantity, and recently, in the march of progress, the



A.D. 1824 . . . . N° 5022.

Artificial Stone.

ASPDIN'S SPECIFICATION.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, Joseph Aspdin, of Leeds, in the County of York, Bricklayer, send greeting.

WHEREAS His present most Excellent Majesty King George the Fourth, by His Letters Patent under the Great Seal of Great Britain, bearing date at Westminster, the Twenty-first day of October in the fifth year of His reign, did, for Himself, His heirs and successors, give and grant unto me, the said Joseph Aspdin, His especial licence, that I, the said Joseph Aspdin, my ex̃ors, adm̃ors, and assigns, or such others as I, the said Joseph Aspdin, my ex̃ors, adm̃ors, and assigns, should at any time agree with, and no others, from time to time and at all times during the term of years therein expressed, should and lawfully might make, use, exercise, and vend, within England, Wales, and the Town of Berwick-upon-Tweed, my Invention of "**An Improvement in the Modes of Producing an Artificial Stone**;" in which said Letters Patent there is contained a proviso obliging me, the said Joseph Aspdin, by an instrument in writing under my hand and seal, particularly to describe and ascertain the nature of my said Invention, and in what manner the same is to be performed, and to cause the same to be inrolled in His Majesty's High Court of Chancery within two calendar months next and immediately after the date of the said in part recited Letters Patent (as in and by the same), reference being thereunto had, will more fully and at large appear

NOW KNOW YE, that in compliance with the said proviso, I, the said Joseph Aspdin, do hereby declare the nature of the said Invention, and the manner in which the same is to be performed, are particularly described and ascertained in the following description thereof (that is to say):—

2 A.D. 1824.—N° 5022.

Aspdin's Improvements in the Modes of Producing an Artificial Stone.

My method of making a cement or artificial stone for stuccoing buildings, waterworks, cisterns, or any other purpose to which it may be applicable (and which I call Portland cement) is as follows:—I take a specific quantity of limestone, such as that generally used for making or repairing roads, and I take it from the roads after it is reduced to a puddle or powder; but if I cannot procure a sufficient quantity of the above from the roads, I obtain the limestone itself, and I cause the puddle or powder, or the limestone, as the case may be, to be calcined. I then take a specific quantity of argillacious earth or clay, and mix them with water to a state approaching impalpability, either by manuel labour or machinery. After this proceeding I put the above mixture into a slip pan for evaporation, either by the heat of the sun or by submitting it to the action of fire or steam conveyed in flues or pipes under or near the pan till the water is entirely evaporated. Then I break the said mixture into suitable lumps, and calcine them in a furnace similar to a lime kiln till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat, or rolled to a fine powder, and is then in a fit state for making cement or artificial stone. This powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar, and thus applied to the purposes wanted.

In witness whereof, I, the Joseph Aspdin, have hereunto set my hand and seal, this Fifteenth day of December, in the year of our Lord One thousand eight hundred and twenty-four.

JOSEPH (L.S.) ASPDIN.

AND BE IT REMEMBERED, that on the Fifteenth day of December, in the year of our Lord 1824, the aforesaid Joseph Aspdin came before our said Lord the King in His Chancery, and acknowledged the Specification aforesaid, and all and every thing therein contained and specified, in form above written. And also the Specification aforesaid was stamped according to the tenor of the Statute made for that purpose.

Dunning, Extr.

Inrolled the Eighteenth day of December, in the year of our Lord One thousand eight hundred and twenty-four.

A 544.

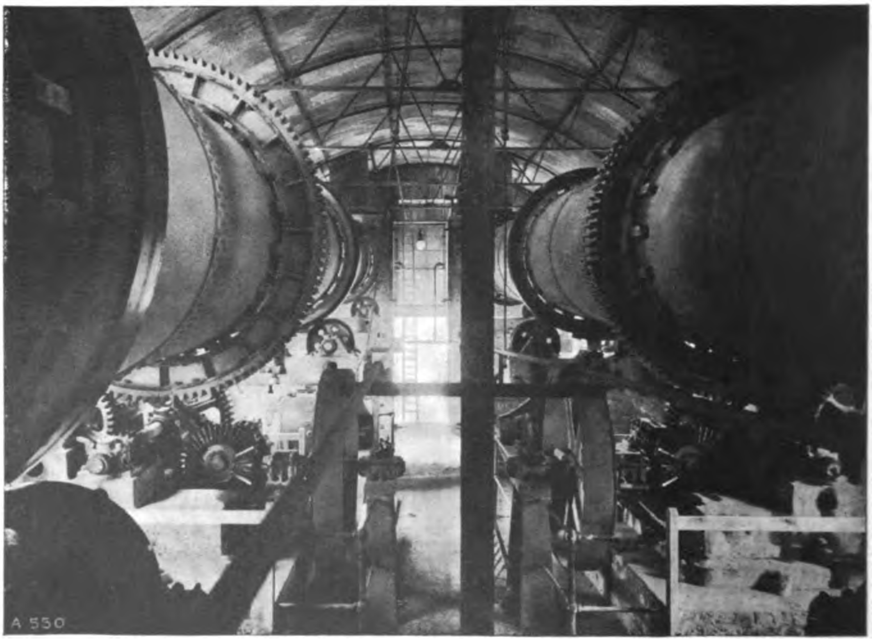
Reproduction of the Original Portland Cement Patent of 1824.

old method of manufacture has given way to the rotary kiln and other plant of modern invention.

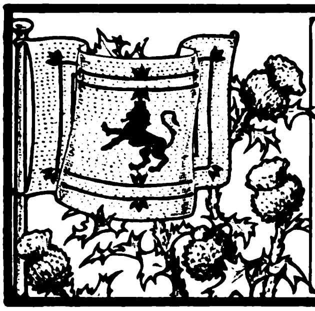
The works of the younger Aspdin, which were for many years carried on by Messrs. Robins, Aspdin & Co., also continued to prosper, notwithstanding the active competition of firms which have since taken very prominent positions in the trade.

As it is a matter of general interest we give illustrations of a battery of old "bottle" kilns, which still exist on the Robins' works, and which are believed to be the oldest Portland cement kilns in the world, and also of a pair of modern rotary kilns of the type which seems destined to displace the older form of burning-plant in the near future.

The great Exhibition in Hyde Park in the year 1851 undoubtedly gave a great impetus to the cement trade, for about this time numerous other factories came into being, mostly on the Thames and Medway, the first works on the latter river having been established at Frindsbury, near Rochester. The works at Faversham, which were established in 1816 for the manufacture of Roman cement and plaster of Paris, and which were subsequently acquired by the well-known firm of Hilton, Anderson & Co., first produced Portland cement in the year 1849. It is unnecessary to refer at any length to the more recent history of the industry. The success of British manufacturers naturally aroused the emulation of foreign countries, and when it was found that the valleys of the Thames and the Medway were not alone favoured by Nature, factories sprang up in France, Germany, and other Continental and transoceanic countries, so that now, although the production of Portland cement in the United Kingdom has reached a gigantic total well exceeding 3,000,000 tons annually, we have been outdistanced by the United States and Germany, each of which produces quantities in excess of these figures.



A PAIR OF MODERN ROTARY KILNS



A REINFORCED CONCRETE FACTORY IN PORTOBELLO, SCOTLAND.

As we have before stated, there is no class of building to which reinforced concrete can be more usefully and economically applied, as far as actual cost and economy in space are concerned, as in factory work.

Important buildings for the cocoa trade have been recently erected for Messrs. Rowntree in York, and we have now pleasure in presenting drawings and description of the factory for Messrs. Schulze in Portobello, near Edinburgh, also erected in this material.

We can only again call attention to owners, both in the cocoa and other trades, to the suitability of using this form of construction for industrial buildings.—ED.

The factory erected by Stuart's Granolithic Co., Ltd., for Messrs. Schulze & Co., manufacturers of chocolate confectionery, Portobello, N.B., is an excellent example of Mr. E. P. Wells's system of reinforced concrete construction.

The building is practically rectangular in plan, the approximate dimensions being 167 ft. by 58 ft., over all, and rising three floors above the basement. The factory is of reinforced concrete construction throughout, with the following exceptions:

The external walls are of ordinary brickwork in cement, with Granolithic stone lintels, quoins, and other dressings. Some of the internal partitions are of brick, and the staircases throughout are of similar artificial stone.

Perhaps the most interesting feature in the construction is provided in the form of foundation adopted. It was originally intended to furnish the external walls and columns with separate foundations, but this arrangement was afterwards superseded. Trenches of 11 ft. width were first excavated along the eastern and southern building lines, but when these had been sunk to a depth of about 12 ft., the clay was found to be of such poor character that it would not be relied upon to carry the proposed superstructure.

The first 3 ft. of clay, however, proved perfectly satisfactory, and it was therefore decided to fill up the trenches already made, which was done with 12 to 1 Portland cement concrete. The whole area was then completely covered with a reinforced concrete cill or raft.

Fig. 1 is a reproduction of the basement plan with various sections, making plain the construction of this cill. The concrete was composed of 4 parts whinstone (⅛-in. to ¾-in. screen), 2 parts sand, and 1 part Portland cement. The total depth is 3 ft., but the upper 3-in. layer was not supplied until the walls and columns were complete, and all centering struck. A 1½-in. complement of Grano. was then added. In the first mass of 2 ft. 9 in. depth, it should, however, be noted that square cavities of 3 ft. 4 in. side and 9 in. depth were left around the centres of all columns, after the construction of which 5 to 1 concrete was filled in (see detail at bottom of *Fig.* 1).

This cill is giving every satisfaction, and is proving quite equal to taking the various heavy point loads that have been brought to bear upon it.

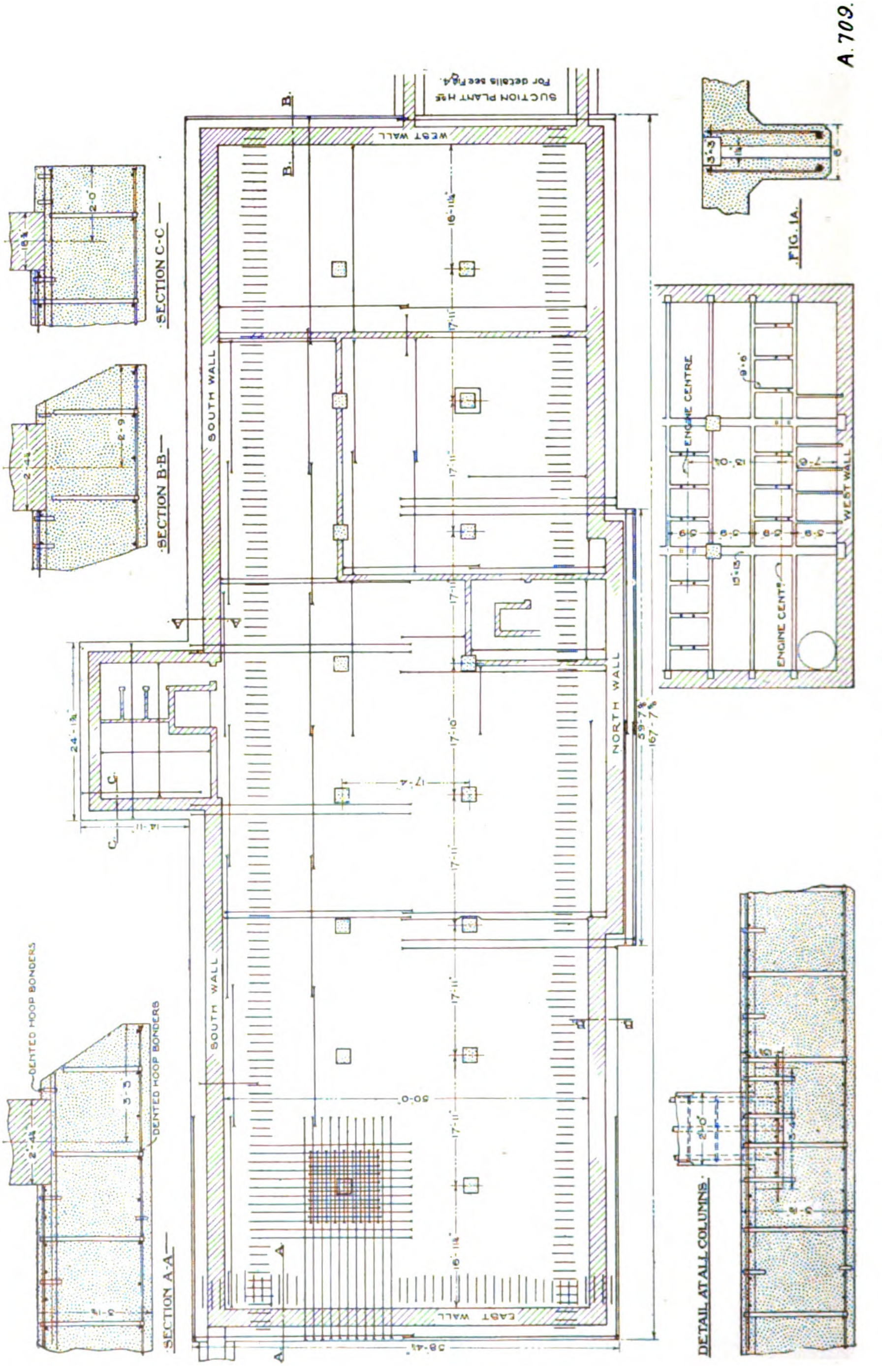


Fig. 1 and 1a. Reinforced Concrete Factory (Working Details).

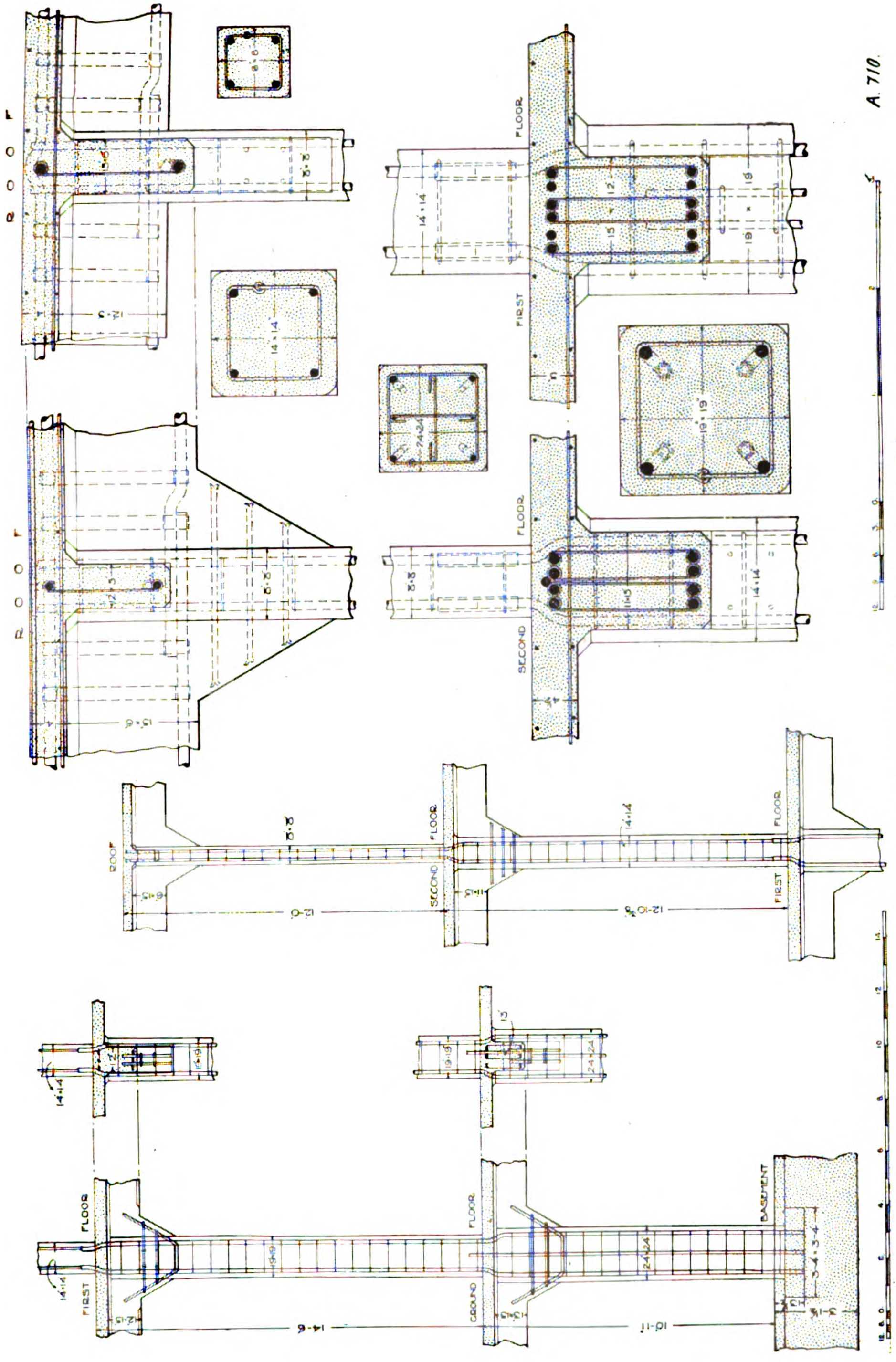


FIG. 2. REINFORCED CONCRETE FACTORY (Working Details).

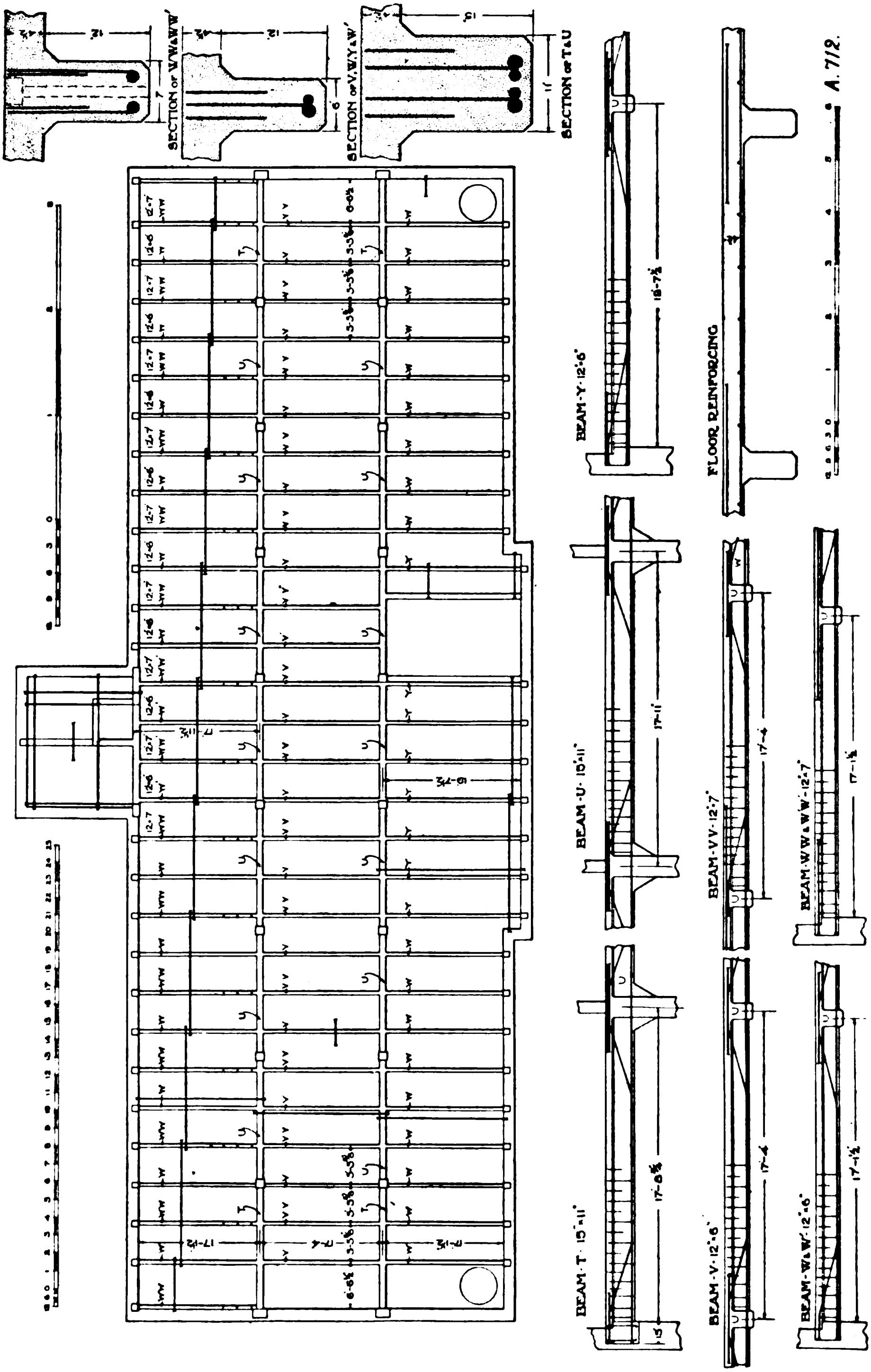


Fig. 3. Reinforced Concrete Factory (Working Details).

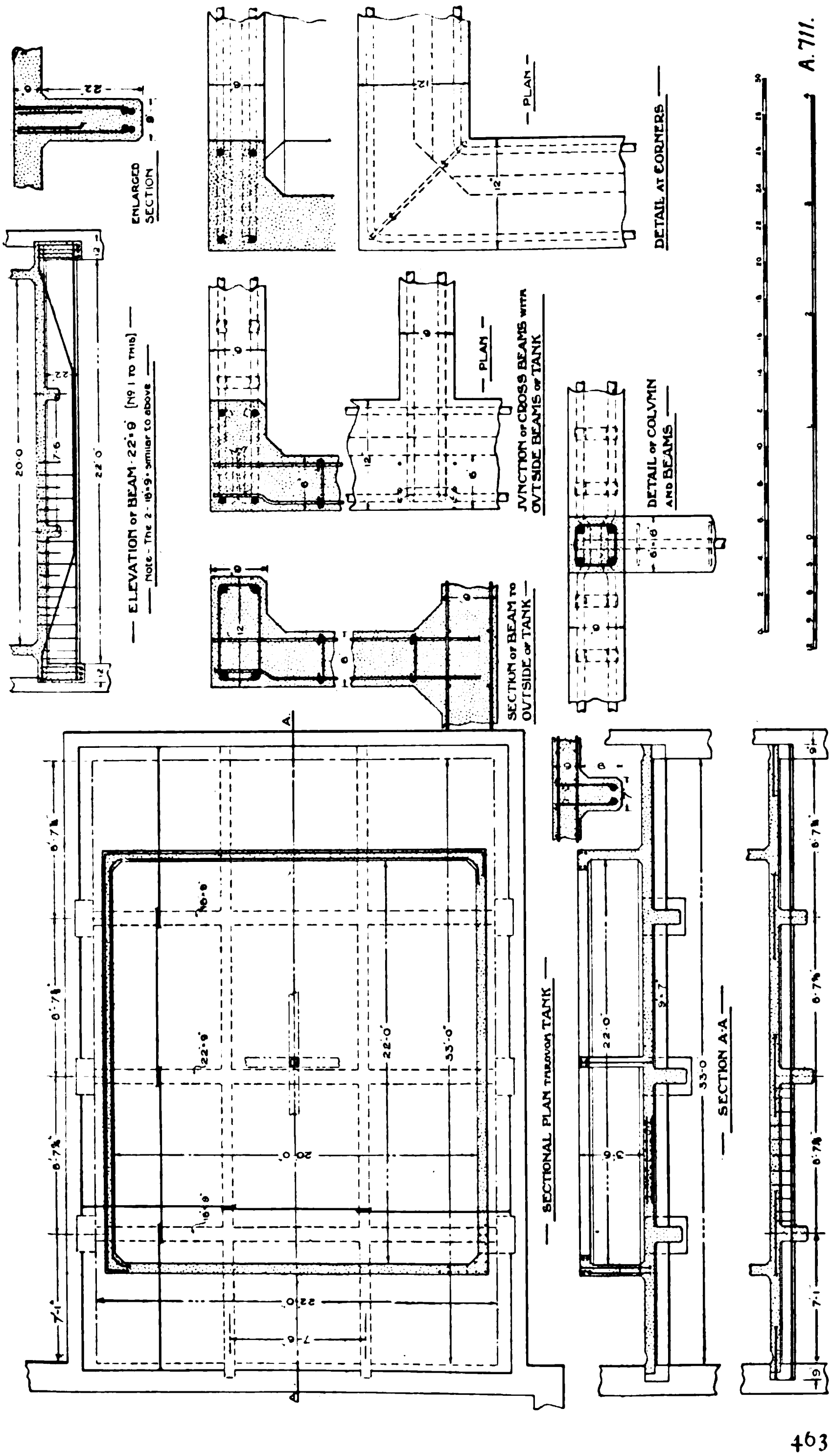

ENLARGED SECTION
ELEVATION OF BEAM 22'9" (Nº 1 TO THIS)
Note - The 2 - 18'9" similar to above
PLAN
DETAIL AT CORNERS
PLAN
JUNCTION OF CROSS BEAMS WITH OUTSIDE BEAMS OF TANK
DETAIL OF COLUMN AND BEAMS
SECTION OF BEAM TO OUTSIDE OF TANK
SECTIONAL PLAN THROUGH TANK
SECTION A-A
BEAM 9'7" × 34'6" Nº 2
A. 711.
A
20'0"
22'0"
33'0"
7'6"
6'7⅞"
7'1"
9'7"
22'6"
16'9"
10'6"

FIG. 4. REINFORCED CONCRETE FACTORY (Working Details)

Fig. 2 gives details of the columns, all of which are identical. A complete member, from basement to roof, will be seen on the left-hand side of the page, divided into two halves. From this the scantlings can be read—24 in. square at basement level, 19 in. square on ground floor, 14 in. square at first floor, and 8 in. square to roof level. The method of reinforcement is made clear by the aid of the four sectional plans, one of which is taken at each level.

The method of graduating the sizes of the vertical rods may bear a word or two of explanation. A ferule is fitted tightly over the larger bar protruding from the floor beneath; the smaller bar is then fitted into the ferule, the space around it being filled up with neat cement grout, just before the concrete is applied. The concrete used for columns was composed of 3 parts whinstone, 2 parts sand, and 1 part cement. The edges of all columns are rounded for about 9 ft. of their height. Details of typical beams will be found in the second-floor plan (*Fig.* 3). Each beam is lettered in the plan to facilitate reference, the details bearing corresponding initials.

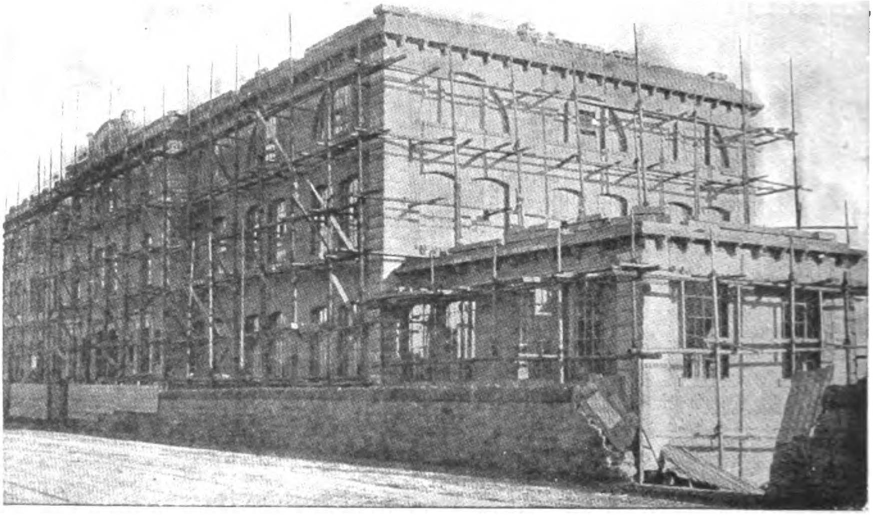


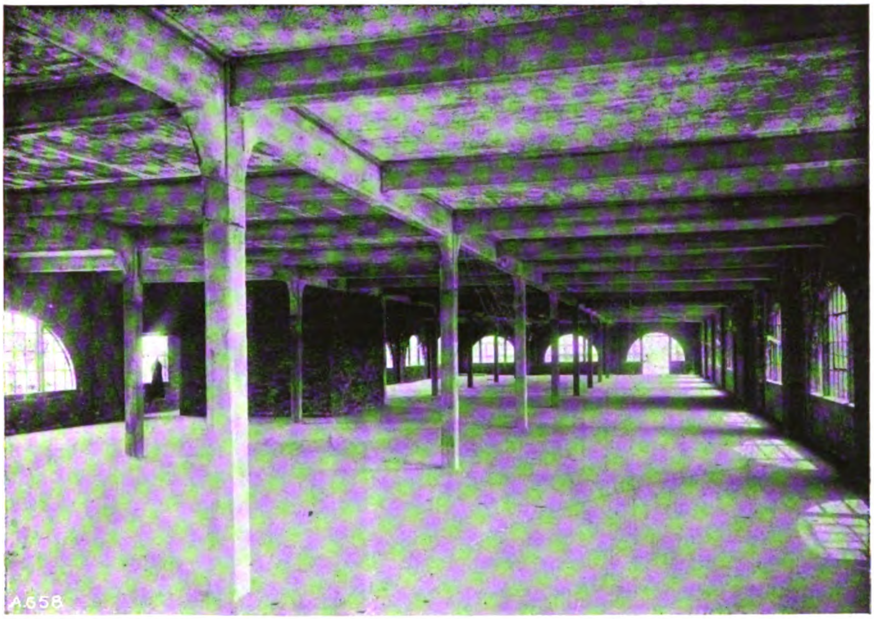
FIG. 5. GENERAL VIEW OF FACTORY.

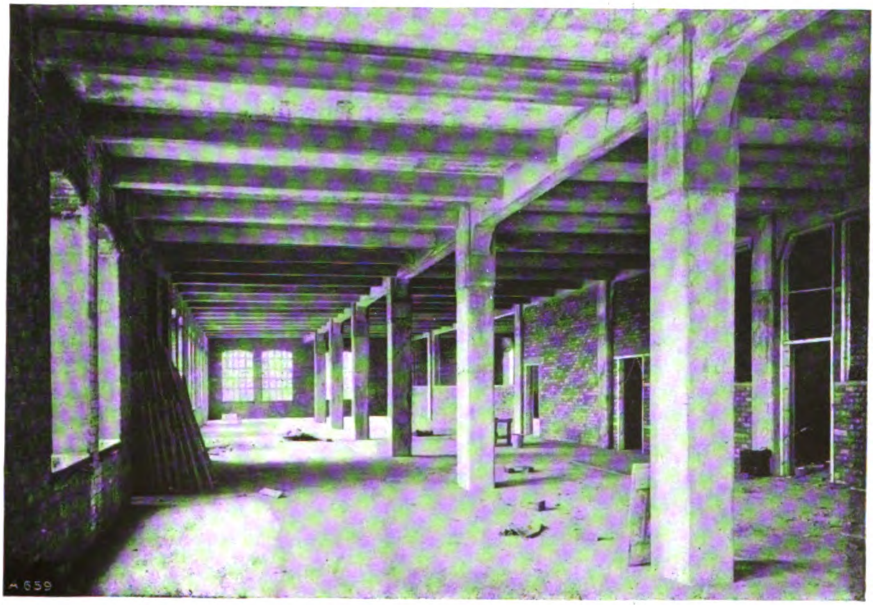
The bar section chiefly used in these beams, as in those throughout the building, is the E. P. Wells' twin, but the arrangement shown in our drawing has been slightly altered to accommodate the bolting of hangers, etc.

The various beam dimensions are shown plainly. The beams have a 1-in. chamfer, and hooks over 6 ft. in length are given a camber of ½ in. The floor slab is 4½ in. thick, and covered with a Grano. finish. The whole has a slight fall towards the back to facilitate flushing operations.

These characteristics obtain generally in the cases of the ground and first floors, each being designed to carry a load of over 3 cwt. per sq. ft., exclusive of the dead or static load. The factor of safety throughout is 4 to 1.

The fact that the ground floor carries the gas engines lends it special interest, and we show a sketch of the western bay in *Fig.* 1a. A cross section through one of the





Figs. 6 and 7. Reinforced Concrete Factory in Portobello, Scotland. Interior Views.

gantry beams is also shown. The bolt hold was obtained by the insertion of an ordinary cardboard tube, stopped at the bottom with a wooden plug, and filled with sand. The floor slab at this level is 5 in. thick.

In regard to the roof, the main beams (running east and west, as shown in *Fig.* 3) are 15 in. by 7 in. with the general span of 17 ft. 11 in. between column centres. The minor beams, which are placed one at, and one between, each column, running north and south, have spans of 17 ft. 4 in. and 17 ft. 6½ in., with scantlings of 12 in. by 5 in. The roof slopes from north to south about 12 in. The slab is 4 in. thick and has a Ruberoid finish.

The Ruberoid in question was applied in two layers of half-ply material, breaking joints, and laid in Ruberoid solution cold, the material being turned up about 6 in. to serve as flashing. The photograph (*Fig.* 8) shows the main roof surface thus covered.

In *Fig.* 4 we show details of the suction-house plant, roof and tank, the position of which can be seen in *Fig.* 1. These are so clear as to need but little description. The concrete used is composed of 2 parts whinstone, 2 parts sand, and 1 part Portland cement.

The tank is rendered inside and out with ¼ in. of 1 to 1, the sand being of the finest description. The roof is slightly graded towards the channels and down-pipes.

Figs. 6 and 7 are photographs of the interior, and give a good idea of the size and general appearance.

We are indebted to the engineer, Mr. E. P. Wells, for the foregoing plans and particulars, and to the contractors, Messrs. Stuart's Granolithic Co., Ltd., and the Ruberoid Co., Ltd., for the photographs.

The architects for the building were Messrs. J. & J. Hall, of Galashiels.

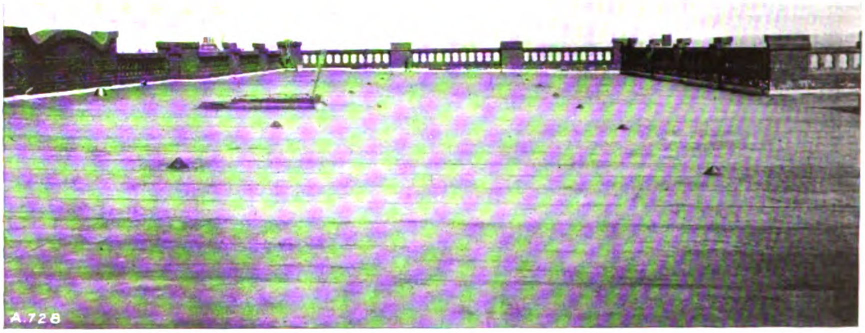


FIG. 8. ROOF OF FACTORY, SHOWING RUBEROID COVERING.

REINFORCED CONCRETE SEA DEFENCES. I.

A DUTCH EXAMPLE.

By H. HUISMAN, C.E., Zierikzee, Holland.

(Translated from the Dutch)

At a period when the question of coast erosion is occupying general attention, the article presented herewith, from the pen of Mr. H. Huisman, should be an interesting contribution on the subject of dykes for low-lying land, indicating as it does the great practical use and economy of reinforced concrete in this class of work.—ED.

IN order to improve the sea defences of the Isle of Schouwen, the engineer, Mr. de Muralt, of Zierikzee, Holland, has recently constructed several new works in reinforced concrete, which claim attention on account of their low cost. At the same time these new works are superior in strength and power of resistance to what had been done previously in the district.

The works constructed on the "Muralt system" may be classified as follows: (a) dyke-walls, (b) protection of the slopes of dykes, (c) protection of the slopes of "sand-dunes," (d) piers and breakwaters, and (e) foundations.

All these works have been executed in concrete, reinforced with "Expanded Metal."

Before proceeding to describe the construction of the dyke-walls, it will be well to explain how, according to Mr. de Muralt's hypothesis, the breaking of a dam generally takes place. (See *Fig.* 1.)

If we take a beam resting on two supports and cause a force P to work upon it in the middle, it will bend deepest in the middle at A. If, however, P works in P^1 the greatest bend will also be very near A (the maximum divergence being only one-twelfth). Now if P^1 is a mobile force the beam will also vibrate most near A—*i.e.*, in the middle part. If, moreover, the beam is very heavy and consists of material that can resist very little drawing force, the vibration caused by a comparatively weak mobile force will soon make it break in the middle. Likewise, if worked upon by a mobile force P^1 not in the middle, a beam on two supports that is very heavy and made of very bad material will not only vibrate most but also break near the middle. (The force P is very small as compared to the weight Q of the beam.) When the beam rests on a number of springs the above still holds good.

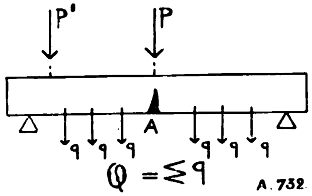


FIG. 1. HEAVY BEAM MADE OF BAD MATERIAL

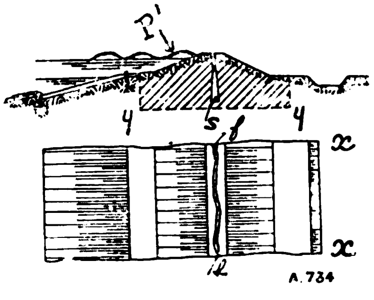


FIG. 2. SECTION OF A DYKE CONSIDERED AS A BEAM.

Now a section of a dyke (*Fig.* 2), breadth *y—y* and length *x—x,* may be considered as a beam which, if there is any layer of fen ground under it, rests on springs. In every severe storm—*i.e.,* whenever the sea-water lashes against the dyke, the body of the dyke cracks internally (at *s*). At the same time the lashing forge P^1 (*Fig.* 2) causes the middle part of the dyke to vibrate most, and soon the crack extends upwards and widens.

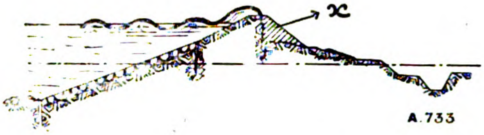


Fig. 3. Landward Slope of a Dyke damaged by water washing over it.

As a rule the existence of such a crack will not make the dyke less seaworthy, unless, as may have happened by way of exception, the sea-water should leak through the base of the dyke, fill the crack with water from below, and cause the part *x* to slide off from the dyke (*Fig.* 3). In a similar way any sliding or shifting of the inner slopes of river dykes are actually caused when the water is high, though it does not flow over the dyke. In the case of sea-dykes, however, where the water is high only for a short time (high floods in Zeeland do not last more than a few hours—the difference between ebb and flood is from 3 to 4 mètres), such a sliding or shifting of the inner slope occurs but rarely.

However, as soon as the water beats against the top, repeatedly drenching the internal parts of the dyke through the crack from the top, the dyke will soon get "muddy," and in consequence of the water pressure the inner slope will soon slide off. (*Fig.* 3.)

A number of breaches were brought about in this way in Zeeland on March 12th, 1906. Many dykes also were cracked in a longitudinal direction (*Fig.* 2 at *f—f*), but did not slide or shift because the water could not get in at the top, these dykes lying high enough, or the water not rising high enough in consequence of their favourable position. This shows that, above all, a sea-dyke should be *high enough.* The difficulty is to obtain height. As a rule it is a comparatively easy matter to obtain the necessary breadth.

After the foregoing explanation it will be clear why Mr. de Muralt constructed his "dyke-topping" in concrete reinforced with "Expanded metal," as follows:

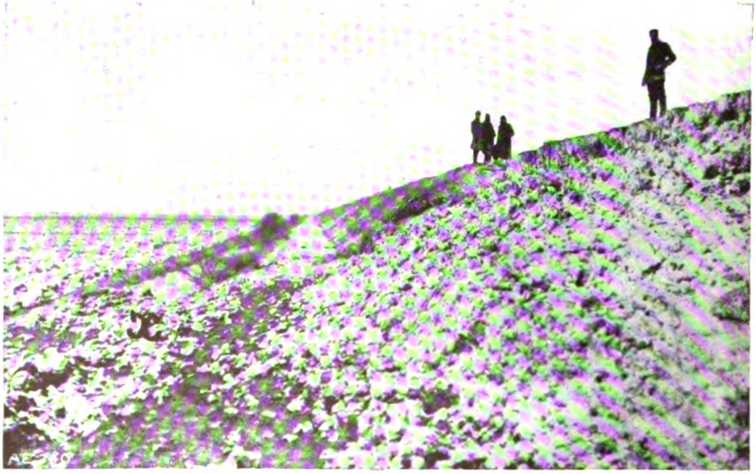


Fig. 4. Sea-Dyke damaged by water washing over it.

The flood of March 12th, 1906, had made it evident that a dyke near Zierikzee was too low. Many longitudinal cracks had been observed, and here and there the inner slope had been carried off by the overflowing water (*Fig.* 4). The dyke had to be made higher by 1·20 m. Its breadth at the top was, and must remain 1 m., so it was impossible to raise the dyke unless it was widened at the same time, either on the inside or the outside. In the latter case an existing basalt pitching would have to be taken up, which would be expensive, and on the inside the course of a road would have to be altered and the necessary land acquired before the widening of the dyke could be effected. Therefore a construction of reinforced concrete on the top was preferred.

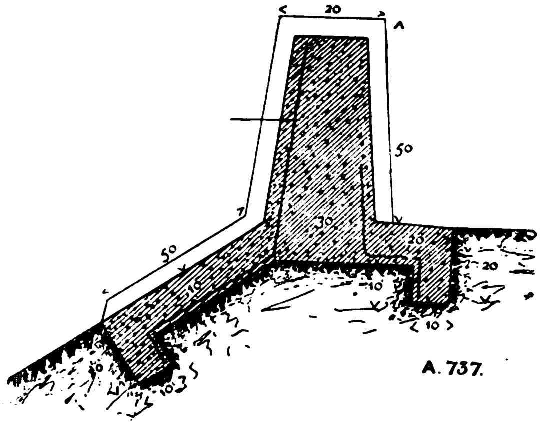


FIG. 5. SECTION OF A WALL ERECTED ON THE TOP OF A DYKE TO MAKE IT HIGHER.

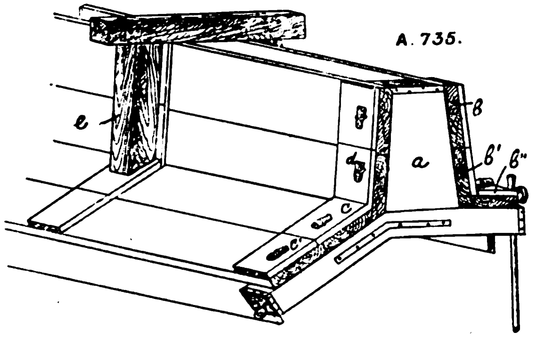


FIG. 6. WOODEN MOULD USED FOR CONSTRUCTING THE WALL.

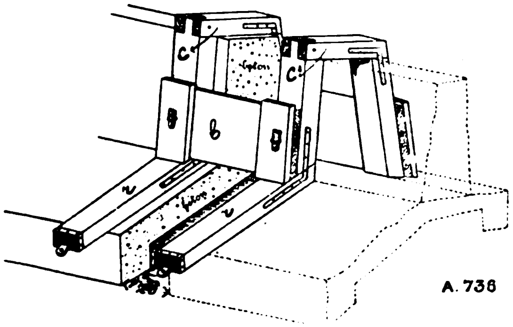


FIG. 7. WOODEN MOULD USED FOR MAKING THE JUNCTION PIECES.

The dyke-walls (*Figs.* 11 and 12) consist of a number of separate parts, between which, after they have become hard, junction pieces are placed. The wall (as sketched in *Fig.* 5) consists of a vertical part resting on a slab which is partly horizontal, and on the outside follows the outer slope of the dyke. The slab and wall form one whole. The wall is raised to such a height that even a flood higher than that of March 12th, 1906, cannot be expected to wash over it; neither could the longitudinal cracks caused by such a flood, in the top-part of the dyke behind the wall, be filled with water.

The line of possible cracks, just in front of the wall, is also covered by the slab facing the outer slope. The surge running up against the wall to overthrow it will, by the pressure of its own weight on the sloping slab, keep the wall in place.

The reinforcing with "Expanded metal" should be done as shown in the sketch. At the knee, above all, it requires to be done very carefully.

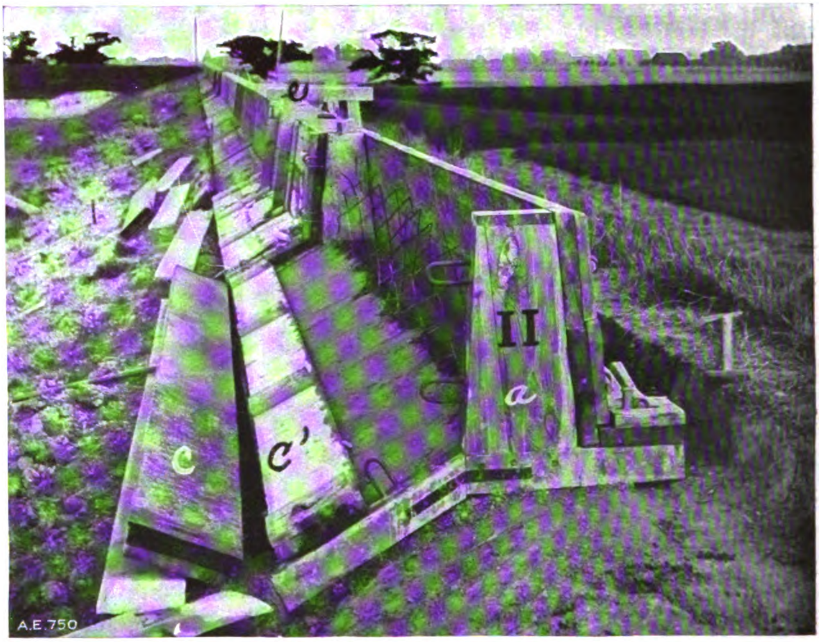


FIG. 8. WOODEN MOULD FOR CONSTRUCTING THE WALL (SEAWARD SIDE).

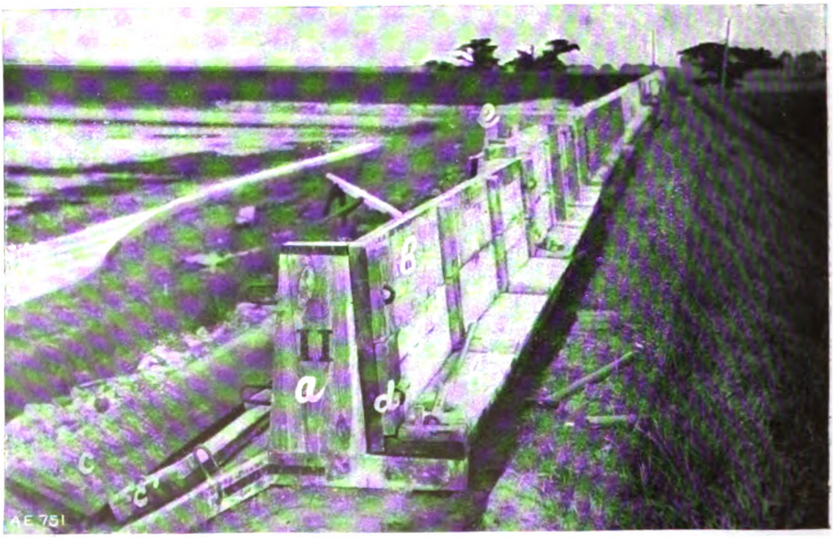


FIG. 9. WOODEN MOULDS FOR CONSTRUCTING THE WALL (LANDWARD SIDE).

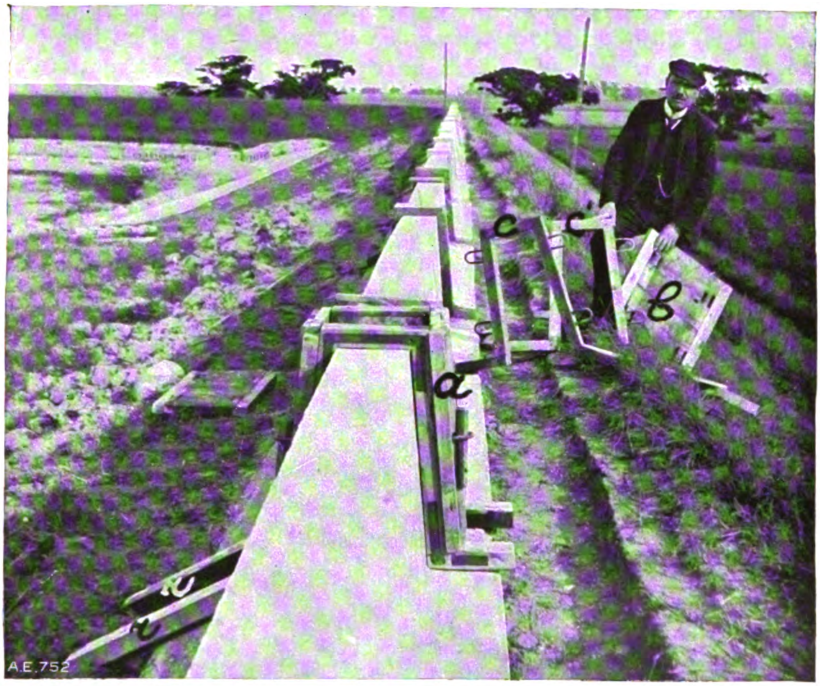


Fig. 10. Putting in Junction Pieces.

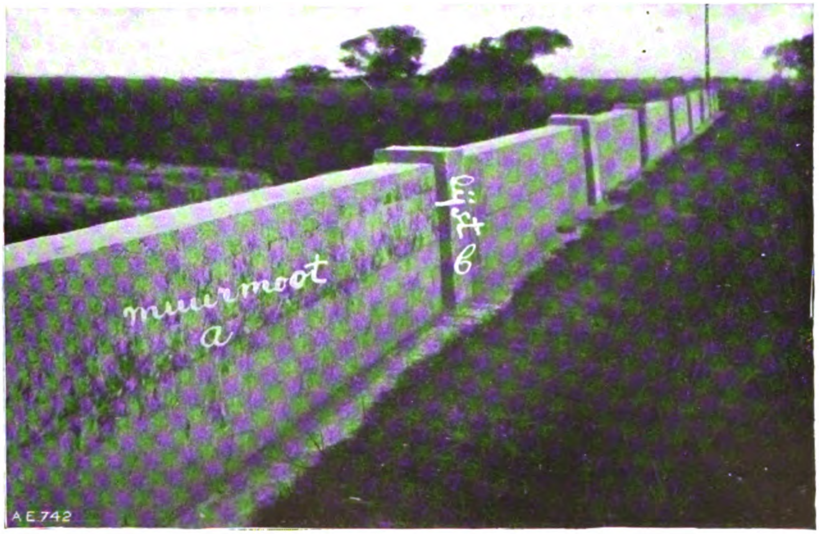


Fig. 12. Wall erected on the top of a Dyke (landward side).

How a slab is to be rammed into the wooden mould may be seen in *Figs.* 6, 8, and 9. As soon as a few sections are finished the junction pieces are put up (*Figs.* 7 and 10) along which the sections of wall are movable. That this movement does not amount to much may be inferred from the fact that on account of its broad base the wall exercises no pressure worth mentioning per c.m. Neither has the contraction of the wall any influence, because the slabs are short (4 m.).

On the above-mentioned dyke, near Zierikzee, 20 per cent. of the expenditure that would have been required to raise the dyke with earth, in the ordinary way, was saved by adopting reinforced concrete. In other places a much greater amount has even been saved, especially where it was difficult to get the earth that was needed, or where there was a road on the top of the dyke for which room would have had to be found elsewhere if the dyke had to be raised by means of earth.

The diagrams and photographs will further illustrate the construction of this reinforced concrete dyke-wall.

The concrete used is composed of 1 part Portland cement, 3 parts sand, 4½ parts gravel, and a half part of trass, mixed with sea-water.

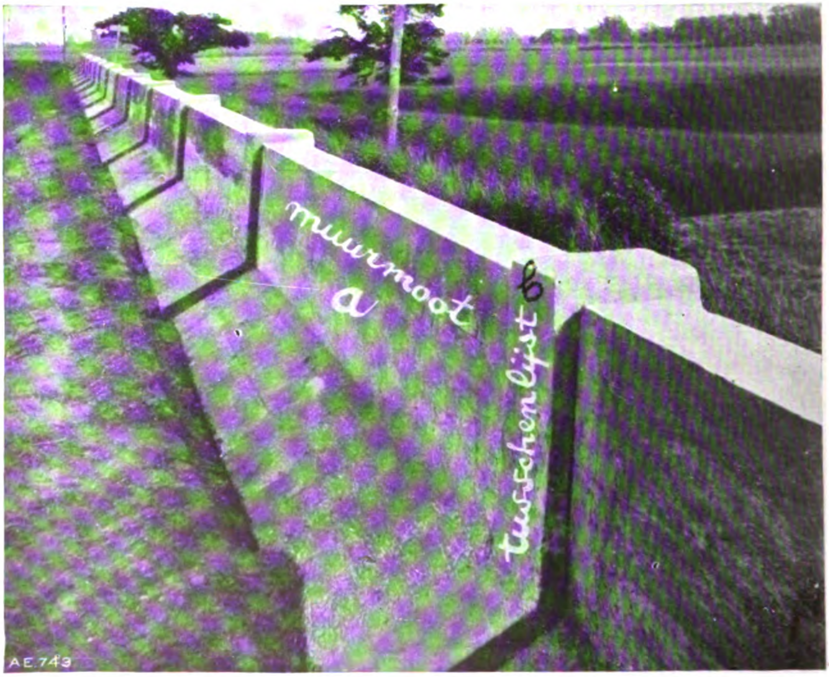
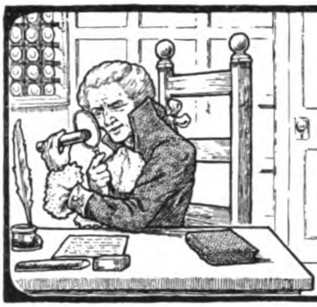


Fig. 11. Wall erected on the top of a Dyke (seaward side).



EXPERIMENTS WITH REINFORCED CONCRETE BEAMS AND COLUMNS, CARRIED OUT BY PROFESSOR TALBOT, 1905 - 1907.

A Summary by CHAS. F. MARSH, M.Inst C.E., M.Inst.M.E., M.Am.Soc.C.E.

The experiments which Prof. Talbot carried out on rectangular reinforced concrete beams during 1904 and 1905 are well known, as is also the theoretical treatment which he has formulated, founded in a great measure on the results of these experiments.
His investigations during the years 1905 and 1906 on the shearing resistance of concrete, and during 1906 on Bond between steel and concrete, together with tests of columns and T-beams, have all of them an important bearing on the design of reinforced concrete, and the results of the work done are here summarised by Mr. Chas. F. Marsh.
A summary is at the same time presented of the research work completed by Professor Talbot, during 1907, with hooped columns of reinforced concrete.—ED.

Professor Talbot's Experiments on the Shearing Resistance of Concrete, 1905-1906.

SHEARING AND BOND.

Shearing of Concrete.—Prof. Talbot's experiments were carried out with three forms of test piece under punching tests and also on restrained beams.

The punching tests were conducted on (1) plain concrete plates; (2) recessed concrete blocks; (3) reinforced recessed concrete blocks. *Fig.* 1 shows these forms of blocks, and *Fig.* 2 shows the restrained beam.

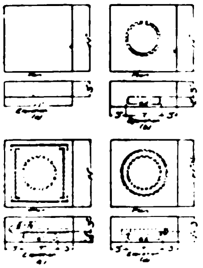


FIG. 1. Forms of Shear Test Piece. (*a*) Plain Concrete Plate. (*b*) Recessed Block. (*c*) and (*d*) Reinforced Recessed Blocks.

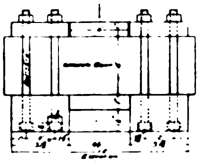


FIG. 2. Restrained Beam Shear Test Piece.

Comparative Tests for Compressive Resistance.—An effort was made to find the compressive strength of concrete in order that comparisons might be made with the shearing strength, but Prof. Talbot states that the making and storing of the test pieces was not altogether satisfactory and consequently the comparisons of strength are not entirely trustworthy.

Both cubes and cylinders were tested in compression.

Compressive Tests.—The resistance of the 6-in. cubes of 1 : 3 : 6 concrete in 1905, varying in age from 59 to 67 days and stored in air, averaged 1,230 lb. per sq. in., and the resistance of similar cubes stored in damp sand in 1906, and varying in age between 59 and 61 days, averaged 2,428 lb. per sq. in. The resistance of 6-in. cubes of 1 : 2 : 4 concrete in 1906, stored in damp sand and varying in age between 57 and 59 days, averaged 3,210 lb. per sq. in.

With respect to the cylinders, which were 8 in. in diameter and 16 in. long and of ages varying from 57 to 61 days, tested in 1906, the average resistance of those of 1 : 3 : 6 concrete was 1,322 lb., and that of those of 1 : 2 : 4 concrete 2,430 lbs. per sq. in.

Shearing of Plain Plates.—The tests on the plain concrete plates showed that tensile stresses were induced and that these contributed largely to the failure. The recessed and reinforced blocks were contrived as an attempt to overcome the defect.

Shearing of Recessed Blocks.—The tests of the plain concrete plates and unreinforced recessed blocks indicated that tensile stresses were the primary cause of failure, these stresses may be likened to the bursting stress developed in a cylinder subjected to internal pressure. The core which was punched out of these specimens always showed cracks on the bottom, and these generally extended one-half to two-thirds the distance to the top.

In every case tension failure at the lateral faces occurred before shearing took place, and it was clear that the ultimate failure was much influenced by this condition. The recessed specimens were better in this respect than the plain plate, and the shearing stresses were evidently more nearly uniformly distributed throughout the depth.

The reinforced recessed blocks failed in a similar manner to those which were not reinforced, except that the cracks appeared later and did not open up when the ultimate load was reached.

The shearing loads were higher for these pieces than for those unreinforced, and the conditions were more favourable for developing the shearing strength, this being more evident in the case of pieces with hooped reinforcement than in that of specimens with straight reinforcements.

Prof. Talbot considers that the objection to this form of test piece is that the manner of applying the load to the top of the piece does not give an even distribution of shear throughout the vertical section.

Shearing of Restrained Beams. — The restrained beam test pieces were 4 in. by 4 in. in cross-section, and 13 in. long, and were so held that a length of $4\frac{1}{8}$ in. was left, on which the loading was applied for a length of 4 in. In the restrained beams the first signs of failure in three specimens, two of 1 : 3 : 6 concrete and one of 1 : 2 : 4 concrete, was the appearance of cracks at the top, as shown in *Fig.* 3 (*a*).

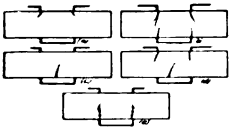


FIG. 3. Manner of Failure in Restrained Beam Shear Test Piece.

These cracks seemed to be caused by a cutting action of the bearing plate or to tension due to beam action.

As the load increased the cracks lengthened and widened, as shown in *Fig.* 3 (*b*), until they finally reached a maximum width of about $\frac{1}{32}$ in. at the top.

In four specimens of 1 : 2 : 4 concrete the first sign of failure was a tension crack, as shown in *Fig.* 3 (*c*), which gradually lengthened and widened as the load increased. Later, cracks appeared at the top, as shown in *Fig.* 3 (*d*). After the maximum load was reached the lower crack gradually closed and the upper cracks gradually widened.

The final shearing action occurred at a load less than the maximum, and evidently took place over a much smaller shearing area than the full section. At the final failure cracks appeared, as shown in *Fig.* 3 (*e*), through a portion of the depth which evidently took the full shear.

Ratio of Shearing to Compressive Resistance.—Prof. Talbot gives several tables showing the results of his experiments in detail, together with a table which gives the summary of the shearing tests and the ratios of the shearing to the compressive resistance, which varies from 0·37 to 0·90 with an average of 0·58 when compared with the compressive resistance of the cubes, and from 0·49 to 1·39 with an average of 0·85 when compared with the compressive resistance of the cylinders.

The conclusions arrived at by Prof. Talbot from the results of these tests were as follows :—

1.—It is difficult to devise a form of test specimen and a method of testing which will satisfactorily determine the resistance of concrete to shear. The difficulties lie in the inability to secure an even distribution of the shear over the shear section, in the high cutting and bearing stresses developed, and in the complications formed by the compressive, tensile, and bulging and bursting stresses developed. The forms of test specimen here used are not fully satisfactory, but information concerning the shearing resistance of concrete may be drawn from the tests as a whole, and tentative values selected. A test specimen in the form of a beam and in which the load is applied evenly over the depth of the beam instead of on the top is suggested.

2.—The resistance of concrete to shear is dependent upon the strength of the stone as well as upon the strength of the mortar, and for the richer mixtures the strength of the stone probably exercises the greater influence. With hard limestone and 1 : 3 : 6 concrete 60 days old the shearing strength may be expected to reach 1,100 lb. per sq. in., and with the 1 : 2 : 4 mixture 1,300 lb. per sq. in. It seems very probable that the resistance to simple shear is considerably higher than this, and that tests made with the load applied evenly over the shearing section will verify this.

3.—Since the compressive strength of concrete is influenced largely by the strength of the cement and the shearing strength is much more influenced by the strength of the aggregate, it does not seem proper to express the shearing strength in terms of the compressive strength. However, this is frequently done and is of advantage in gaining a conception of their relative action. It appears that the shearing strength is, in general, at least 50 per cent. of the compressive strength, and that it may exceed 75 per cent. The apparent exception to this is explained by the high values obtained in the 1906 compression tests. These conclusions agree in a general way with the statement of Feret and others that the shearing strength is as much as two-thirds of the compressive strength. Evidently the shearing strength of concrete is several times its tensile strength.

Bond.—Prof. Talbot carried out some experiments on the bond between steel and concrete in 1904, in which he used square, round and deformed sections. In 1906 he carried out a further series of experiments, which included tests for bond resistance of rods with a smooth surface of uniform section like cold rolled shafting, the effect of richness of concrete and of the depth the bar is embedded and the resistance of flat bars. He also determined the value of the running friction or the resistance to sliding still remaining after the bars had begun to slip, and the tensile stress developed in the bars.

The elastic limit of the mild steel was about 38,000, that of the cold rolled shafting about 87,000, that of the tool steel about 53,000, and that of the flat bars about 45,000 lb. per sq. in.

The average resistances obtained were as follows :—

Type of rod.	Kind of concrete.	Bond: lbs. per square inch of surface.	Running friction lbs. per square inch of surface.	Ratio of running friction to bond.	Encased lengths: inches.	Stress developed in steel: lbs. per square inch of sectional area.
Plain round	1 : 3 : 5½	376	233	62 %	6 12	15.702 33.366
" "	1 : 2 : 4	424	253	59·7 %	6 12	19.045 31.714
Cold rolled shafting ...	1 : 3 : 5½	147	58	40·5 %	6	5,403
Flat mild steel	1 : 3 : 5½	125	84	67·1 %	6	9.026
Round tool steel ...	1 : 3 : 6	147	—	—	6	4,700

The bars were embedded in cylindrical blocks of concrete 6 in. in diameter, the bar being flush with one end of the cylinder and projecting from the other to allow the pulling head of the testing machine to obtain a grip. Two mixtures of concrete were used, being 1 : 3 : 5½ and 1 : 2 :4.

The conclusions arrived at by Prof. Talbot from the results of these tests are as follows :—

1.—Little difference is found in the bond resistance per sq. in of surface of bar in contact with the concrete whether the bar is embedded 6 in. or 12 in. Evidently a length may be found beyond which the stretch of the steel would cause uneven distribution of the bond stress along the length of the bar and cause failure to begin at the point of greatest stress in the steel and thus give results not representative of the real bond resistance. This limitation applies to the length for use in experimental tests of bond. In simple beams the bond stresses are applied along the length of the bar, and stretch and bond exist together.

2.—The richer mixture of concrete gives somewhat higher bond resistance than the leaner—the values for the 1 : 2 : 4 concrete averaging, say, 10 per cent. to 15 per cent. higher than the 1 : 3 : 5½ concrete. For plain round mild steel rods, the average for the bond resistance ranges from 350 to 450 lb. per sq. in. of contact surface.

3.—The flat bars gave much lower resistance than round bars. Only three tests were made with flat bars, and these may not be representative. It may be noted that the results with flat bars are much lower than tests made elsewhere. It should also be noted that for a bond stress of 125 lb. per sq. in., the tensile stress developed in the bar was only 9,000 lb. per sq. in.

4.—The value of bond resistance will depend upon the smoothness of the surface of the bar, the uniformity of its diameter and section, the adhesive strength of the concrete, and the shrinkage grip developed in setting. The effect of smoothness of surface and uniformity of diameter and section is seen in the tests made with cold rolled shafting and tool steel. The average bond developed with cold rolled shafting and tool steel was 147 lb. per sq. in. of contact surface, as compared with about 400 lb. per sq. in. for ordinary plain, round, mild steel rods. It should be stated that not only was there a very noticeable difference in the smoothness and finish of the surface of the rods, but the section of the cold rolled shafting and tool steel was very uniform, the diameter not varying more than ·0001 or ·0002 in. at ¼-in. intervals throughout the length, while mild steel rods will vary as much as ·0015 in. It is to be expected that the smoothness and uniformity of section of drawn steel wire will operate to give low values of bond resistance, though, of course, as the section of wire is small compared with the circumference, the bond stresses developed when wire is used are relatively small. Attention is called to the fact that in former tests of reinforced concrete beams the bond stresses developed in beams failing by tension of the steel, diagonal tension of the concrete or other similar methods amounted to from 73 to 193 lb. per sq. in. Even at the breaking load, then, the bond stress developed in the mild steel rods was far below the bond resistance found in these tests.

5.—In these tests the bars began to slip when the maximum load was reached. After slipping began, the resistance to motion was still considerable. This running friction, taken when the bar had moved about ¼ in., amounted to 54 per cent. to 72 per cent. of the bond developed in the case of mild steel bars and to 32 per cent. to 49 per cent. in the case of the cold rolled shafting.

PLAIN AND REINFORCED CONCRETE COLUMNS.

The reinforced concrete columns tested by Prof. Talbot during 1906 only included those with longitudinal reinforcements, and binding relatively far apart in some cases, hooped columns being left for a special series of subsequent tests.

The proportions of the loading carried by the concrete and the steel was also estimated. From the results of his tests Prof. Talbot discusses formulæ for reinforced concrete columns, and the factors of safety to be employed.

Prof. Talbot included in his discussions the results of a series of column tests carried out at the Watertown Arsenal, and these he compares with the results obtained by himself.

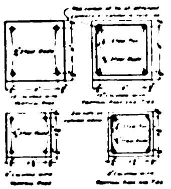


Fig. 4. Arrangement of Reinforcement.

The concrete for the column tests was mixed in the proportions of 1 to 2 to 2¾, as this gave a smaller percentage of voids with the materials used than a 1 : 2 : 4 mixture.

In addition to the columns, 17 cubes 12 in. on the edge of 9 cylinders 8 in. diameter and 16 in. long, all of plain concrete, were tested. The columns were of plain concrete, concrete reinforced with vertical rods only, and concrete reinforced with vertical rods with bindings of steel ¼ in. rods. *Fig.* 4 shows the various types of reinforced columns.

The average ultimate resistance of the rods was 59,200 lb. per sq. in., and the average limit of elasticity was 39,800 lb. per sq. in., the average percentage of elongation in a length of 8 in. was 30·9. Table I. gives the details of the columns and the resistance on the gross section and the nature of the failure.

TABLE I.

SUMMARY OF COLUMN TESTS.

Col No.	Nominal Size in. × in. × ft.	Area of Cross-section sq. in.	Reinforcement.			Maximum Load lb. per sq. in. of Gross Section	Age days	Manner of Failure.
			Kind.	Area.				
				sq. in.	per cent.			
1	12×12×12	147.4	4—¾-in. rods	1.77	1.20	1587	71	Crushed on one side, 4 ft from bottom
2	9× 9×12	80.6	4—⅝-in. rods	1.23	1.52	1577	69	Crushed out near top
3	12×12×12	146.2	4—¾-in. rods 12—¼-in. ties	1.77	1.21	1862	71	Crushed out 1 ft. from bottom. Rods finally buckled
5	12×12×12	146.4	Plain	0.	0.	1710	69	Crushed and sheared diagonally, 1½ ft. below top
6	9× 9×12	80.9	4—⅝ in. rods	1.23	1.52	1600	70	Crushed out 1 ft. from bottom. Rods finally buckled
7	12×12×12	145.5	4—¾-in. rods	1.77	1.21	1850	65	Crushed and sheared 5 ft. from bottom
8	9× 9×12	80.8	Plain	0.	0.	2004	64	Top sheared off
9	12×12×12	146.6	Plain	0.	0.	1610	65	Crushed and sheared off at top
10	9× 9×12	82.0	4—⅝-in. rods 12—¼-in. ties	1.23	1.50	1280	65	Crushed out 1 ft. from bottom. Rods finally buckled
11	12×12×12	145.2	4—¾-in. rods 12—¼-in. ties	1.77	1.21	1936	65	Crushed 1½ ft. from top
12	9× 9× 9	82.7	4—⅝-in. rods 9—¼-in. ties	1.23	1.48	2335	66	Crushed 1 ft. below top
13	12×12×12	148.8	Plain	0.	0.	1709	61	Crushed in middle of length
14	9× 9×12	82.0	4—⅝-in. rods 12—¼-in. ties	1.23	1.50	1367	63	Crushed 1½ ft. below top
15	12×12× 6	148.0	Plain	0.	0.	1189	63	Crushed 1 ft. from top
16	9× 9× 9	82.5	4—⅝-in. rods 9—¼-in. ties	1.23	1.49	1607	59	Crushed at centre. Rods finally buckled
17	9× 9× 6	83.6	4—⅝-in. rods	1.23	1.47	2206	67	Crushed 1 ft. from top. Rods finally buckled
18	9× 9× 6	83.6	Plain	0.	0.	1079	65	Crushed 1 ft. below top

Fig. 5 shows some typical failures.

The average loads borne by the cubes and cylinders were 2,100 and 1,490 lb. per sq. in. respectively.

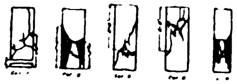


FIG. 5.—Typical Failures.

Loads taken by the Concrete and the Steel in Columns.—The method adopted by Prof. Talbot in apportioning the resistance between the steel and the concrete is very ingenious.

He plots the load deformation curve for the combined column, then assuming the co-efficient of elasticity of the steel to be 30×10^6 lb. per sq. in. he plots the straight line, giving the load deformation curve for the steel distributed over the entire sectional area of the column.

For instance, for a deformation of 0·001 in. the stress in the steel is 30,000 lb. per sq. in. and for a column having a reinforcement of 1½ per cent. of its total sectional area, the load taken by the steel is equivalent to 450 lb. per sq. in. distributed over the whole sectional area for this deformation. Having plotted the load deformation curve for the steel, the intercepts on the vertical ordinates between this straight line curve and the load deformation curve for the gross cross-section give the ordinates for the load deformation curve of the concrete alone. If this is plotted from the zero horizontal line of the diagram it gives the true load deformation curve for the concrete.

A typical diagram of this nature is given in *Fig.* 6.

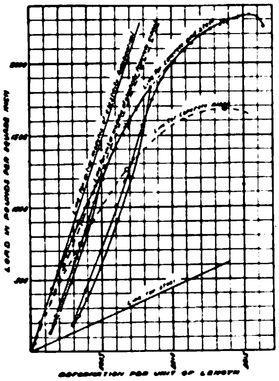


FIG. 6. Stress-Deformation Diagram for Column No. 12.

This figure shows the load deformation curve of a column subjected to repetition of loading. The load deformation curve for the gross area of the column is taken as continuous through the various loadings, and not as what may be called the true elastic curve, for which the deformations would be obtained by deducting the several permanent sets found at each unloading.

Prof. Talbot considers that the curve so obtained is more accurate for practical purposes than that obtained from the true elastic deformations.

The load deformation curve obtained as above is parabolic, and the tangent to the curve at the origin gives the line for initial modulus of elasticity for the concrete. It will be noticed that the point of maximum resistance of the concrete occurs at a smaller deformation than that of the gross section; this point on the curve occurs at that deformation at which a line parallel to the steel load of deformation curve is tangential to the curve for the combined section. Beyond this point, while the column as a whole may sustain a larger load, a greater proportion of this is taken by the steel, while the concrete has passed at maximum carrying capacity.

For the lower range of stresses the load deformation curve for the concrete alone does not vary greatly from a straight line, but it deviates more and more as the ultimate resistance is approached. (The instantaneous modulus or co-efficient of elasticity at a load of 500 lb. per sq. in. will be somewhat less than the initial modulus, and the instantaneous modulus becomes less and less until the maximum resistance is reached.) At the maximum compressive resistance Prof. Talbot concludes that the ordinate to the load deformation curve is one-half that to the line for the initial modulus of elasticity, or the ordinate to the load deformation curve which would be the result if the concrete were a truly elastic material, and at half the ultimate deformation the ordinate will be only three-quarters of that of the line of initial modulus of elasticity.

The average values for the concrete alone obtained from the plain and reinforced concrete tests are 1,553 and 1,243 lb. per sq. in. respectively, and the average maximum stresses as calculated on the assumption that the load deformation curve of the concrete alone is a true parabola, and in the case of the reinforced columns the maximum stresses on the gross area, including the reinforcements, are 1,550 and 1,247 lb. per sq. in. for plain and reinforced columns respectively.

The average initial modulus of elasticity for both plain and reinforced columns is $2{\cdot}25 \times 10^6$ lb. per sq. in.

It will be noticed that the average maximum stress taken by the concrete in the reinforced columns is less than that for the plain columns, and from Prof. Talbot's tables it also appears that the range of results is greater. This may be partly accounted for by the fact that the reinforcing rods terminated about half an inch from the ends of the columns, but Prof. Talbot is doubtful on this point, and considers that the deficiency of resistance indicates that care should be taken not to use too high working stresses in columns reinforced with longitudinal rods with bindings at relatively considerable distances apart.

Prof. Talbot gives tables obtained from the published records of the Watertown Arsenal experiments of 1904, which were carried out using concrete mixed in the proportions of 1 : 2 : 4, and reinforcements of Thacher, Ransome and corrugated bars, from which the average results are as follows :—

Average initial modulus of elasticity, $2\cdot5 \times 10^6$. Stress in concrete, 1,590 lb. per sq. in., and a calculated stress on concrete, on the supposition that the load deformation curve of the concrete is a true parabola, of 1,620 lb. per sq. in.

These agree very closely with the results obtained by Prof. Talbot.

The results obtained from the Watertown Arsenal experiments indicate that there is no marked characteristic difference in either stiffness or strength for columns made with any special form of reinforcing bar.

Prof. Talbot discusses the basis for working stresses and factors of safety. He points out that in steel we have a material whose properties are fairly definitely known, and, basing our point of failure at the elastic limit, we have a sure basis on which to found the factor of safety against the variations of working conditions, such as uneven distribution of load, unconsidered stresses due to settlement, etc., and for the variation in the material and faulty workmanship. Concrete, however, is a material which has no definite elastic limit which can be used as a starting point, and, consequently, other considerations, such as the lack of uniformity of the material, the effect of increased deformation, of repetitive loading, of time, etc., must be considered.

Prof. Talbot comes to the conclusion that no higher stress should be allowed for a basis to which we may apply the factor of safety than that which gives a deformation equal to one-half the ultimate deformation, which, from the parabolic relationship of stress and strain, is a stress equal to three-quarters the ultimate resistance. To this value we must apply a factor of safety to cover the variation of working conditions referred to above. Prof. Talbot also deals with the ratio of stress in the steel to that in the concrete, he objects to this ratio being referred to as the ratio of the moduli of elasticity of the concrete to that of the steel, as this definition assumes a constant modulus for the concrete, he gives a table showing that this factor varies, on an average, for various ratios of deformation, as follows :—

Ratios of deformation to that at the maximum compressive resistance of the concrete	0	⅛	¼	½	1
Ratios of modulus of elasticity of steel to the initial modulus of elasticity of concrete	13.15	14.55	15.25	17.75	26.15

It would appear from this table that the usually-accepted value of 15 is quite sufficiently accurate for formula based on working resistance.

After discussing the conditions of column construction as ordinarily carried on in building construction, and emphasising the necessity of care in the selection of working stresses and advising the use of a fairly rich concrete made of good-grade cement, Prof. Talbot summarises his conclusions as follows :—

1.—In discussions involving the strength and stiffness of concrete, the variability of the concrete must be taken into consideration. Test columns made with care to secure uniformity of conditions show considerable diversity in quality. An even greater variation in character must be expected under the conditions of ordinary building construction.

2.—Cubes and other small test specimens are made under conditions which give a stronger and denser concrete than is generally found in full-sized pieces in building work. The restraining effect of the bearing plates of the testing machine also influences the results of cube tests. It is evident that the test pieces used in many tests recorded in engineering publications were made with a quality of materials, methods of fabrication, and conditions of setting which are far more favourable to high results than will be found under average conditions of construction. Caution should therefore be used in accepting as a basis for design values obtained from tests without knowing fully all the conditions accompanying the investigation.

3.—The relative amount of load taken by the concrete and by the steel, in columns with longitudinal reinforcement, may be determined by means of the observed relation between loads and deformations under the assumption that the stress in the steel reinforcement is proportional to the deformation in the column. It is assumed that the bond between the steel and the concrete is adequate. This method forms an efficient means for discussing the relative stresses in steel and concrete.

4.—By the method of analysis used, the average maximum stress in the concrete for the reinforced columns tested is found to be 15 per cent. less than the average for the plain concrete columns. While this may not be taken as a final or representative conclusion, since it may be merely incidental to the columns used or the method of testing, it is at least an added reason for caution in choosing working stresses for this form of construction. The average total load taken by the reinforced columns, it should be understood, was considerably higher than the average for the unreinforced columns.

5.—The plotted diagrams representing the loads or stresses in the columns and the corresponding deformations or shortenings (stress-deformation diagrams), show a variable relation which is well expressed by the parabola The tangent to the parabola at the point of zero load represents by its slope the initial modulus of elasticity of the concrete, and forms a convenient basis for an expression for the variable relation between stress and deformation. It should not be inferred that this relation is generally applicable to very rich or very lean concrete. The "Line for steel" in the diagrams for reinforced columns is helpful in determining the stress taken by the concrete and by the steel.

6.—Gross (total) deformations and not net (elastic) deformations are used, since in the application of the stress-deformation relation to columns and beams gross deformations will, under the hypotheses ordinarily accepted, enable the stress in the steel to be determined, and net values will not.

7.—The fact that during the operation of releasing a load the stress-deformation diagram does not follow the parabola but takes a course which approximates a straight line, is not a valid reason for not accepting the parabolic relation in the analysis of beam and column action. When a beam has been loaded up to a given load, the area of the part of a section above the neutral axis is in compression, and no point of this section has been strained beyond the amount then developed at that point, each point having the highest stress which has come upon it. The effect of repeating a load on a beam in progressively increasing amounts is to increase all the deformations in the section, but the resulting curve will still resemble the parabola, and the resulting initial modulus of elasticity will have a smaller value than that found for the first application of loads.

8.—The Watertown Arsenal tests of columns of composition similar to the University of Illinois columns are comparable in strength and stiffness and in the form of stress-deformation diagram and tend to confirm the results and conclusions of the University of Illinois tests. The average maximum compressive stress taken by the concrete in the Watertown Arsenal columns was 1,590 lb. per sq. in. In the University of Illinois columns it was 1,550 lb. per sq. in. for the plain columns and 1,290 lb. per sq. in. for the reinforced columns.

9.—The average value of the initial modulus of elasticity given for the University of Illinois columns, 2,250,000 lb. per sq. in., and that for the Watertown Arsenal columns, 2,500,000 lb. per sq. in., may be considered tentative values for 1 : 2 : 4 concrete of the kind described for use at an age of 60 to 105 days and first application of load. Age will increase the modulus and repetition decrease it. What the combined effect of these two agencies will be is not known, but it will vary with the conditions of materials and number of repetitions and also with the age at which loads are first applied. When a constant modulus of elasticity (straight-line relation) is used, the value chosen should be less than that for the initial modulus here given. The high values of modulus of elasticity frequently quoted are doubtless due to shortness of length of test piece, high quality in the test pieces used, use of elastic deformation, etc. The quality of the aggregate, as well as of the cement used in making test pieces, may not always be representative of that used in building operations.

10.—The proper basis for working factor and working stress for use in designing with any given material and form of construction is of much more importance than is usually given to it. The conditions of loading, of transmission and distribution of load, of variation in fabrication and construction, all act to make the stress actually developed in a member of a structure greater than the assumed working stress. For steel the real basic point is the elastic limit or yield point. For concrete this basic point may well be considerably below its ultimate strength. The choice of a value corresponding to a deformation equal to one-half of the deformation at point of failure is suggested. This, by the parabolic relation, is equal to three-fourths of the ultimate strength. Having selected a basic point, a working factor to obtain the working stress will then be chosen to cover contingencies and emergencies and the variations in distribution of load, quality of materials, method of fabrication, nature of load and its manner of application, etc. The range in the values for the working factor which may be used under the various conditions of repetition of load, workmanship and material, is of course much greater with concrete than will be necessary with such a material as mild steel.

11.—The ratio between the amount of stress taken by the steel and that taken by the concrete in columns reinforced with longitudinal rods varies as the load is increased, as may be expected from the variable stress-deformation relation of the concrete. In these tests this ratio varied from 12 at the initial application of the load in one column to 34 at the maximum strength of the concrete in another. For the average initial modulus of elasticity of the concrete, the range is from 13½ at the zero load to 26¾ at the ultimate. For very rich concrete the effect of the additional stiffness and the lower final deformation is to decrease the ratio ***m***, and for lean concrete the smaller modulus and greater final deformation will make it larger.

12.—If we choose the half-way deformation for our basic point, the value for the ratio of stress in steel to stress in concrete may, from the two sets of experiments, be taken as 17 to 18 for 1 : 2 : 4 concrete of the quality used in the tests. However, this ratio may properly be taken to be even higher than an average value, since for columns weaker than the average column the ratio may be expected to be higher than the average value and hence to fit the conditions of such columns better, while for columns stronger than the average the added strength of the concrete will go to make up for the over-estimated stress in the steel. For this assumption, 18 to 21 may be used.

13.—Under the conditions of building construction, columns may form a weak element in the structure. To overcome this, the working stresses should be kept low and every precaution taken to secure proper materials, workmanlike fabrication, and efficient inspection.

TABLE II.

LIST OF TEST SPECIMENS.

All Beams have Stirrups of ½ in. Johnson Bars placed as shown in Fig. 8.

T-beams				
T-beam No.	Width of Flange inches	Reinforcement		
		Kind	Area	
			sq. in.	%
1	16	3 ¾-in. Johnson bars	1.68	1.05
2	32	6 ¾-in. Johnson bars	3.36	1.05
3	24	4 ¾-in. Johnson bars	2.24	0.93
4	16	4 ¾-in. plain round	1.76	1.10
5	32	{6 ½-in. Johnson bars {2 bars bent up	3.36	1.05
6	24	{5 ¾-in. plain round {2 bars bent up	2.20	0.92
7	16	4 ¾-in. plain round	1.76	1.10
8	24	{5 ¾-in. plain round {2 bars bent up	2.20	0.92
9	32	{7 ¾-in. plain round {3 bars bent up	3.08	0.97

T-BEAMS.

Prof. Talbot's experiments on T-beams were conducted on 9 beams 11 ft. long and with a span of 10 ft.

The thickness of the flange or slab was 3¼ in., the width of web 8 in., the depth over all being 12 in., and the depth from the top surface to the axis of the reinforcement 10 in. The width of the flange or slab and the description and percentage of reinforcement varied. (See Table 2.)

The percentage of reinforcement is that to the area of the rectangle formed by the total width of the slab multiplied by the depth from the upper surface to the axis of the reinforcement. In some beams a part of the rods were turned up beyond the third points to within 4 in. of the top of the beams.

Ten U-shaped stirrups of ½ in. high carbon indented steel bars spaced 6 in. apart, between the load joints and the supports, were used in each beam (see *Fig.* 8). The loading was applied at the points of one-third the span. In beams Nos. 5 and 9, ½-in. indented steel bars were placed transversely in the upper flange, as shown. In some of the beams the upper layer of bars sank down until they were in contact with the lower layer of bars.

The general phenomena of the tests of the T-beams were quite similar to those attending the tests of rectangular beams having a similar percentage of reinforcement. When the tension in the steel reached 13,000 to 20,000 lb. per sq. in., minute vertical cracks became visible in the concrete on the lower part of the faces of the stem of the T-beam at points in the middle third of the span length. These grew more distinct as the load was increased. When the load became sufficient to strain the steel to its yield point, these cracks opened up and finally became quite large and extended up into and along the flange of the beam. The evidences of failure by tension in the steel were apparent in every beam, as much so in those reinforced with corrugated bars as in those having plain rods.

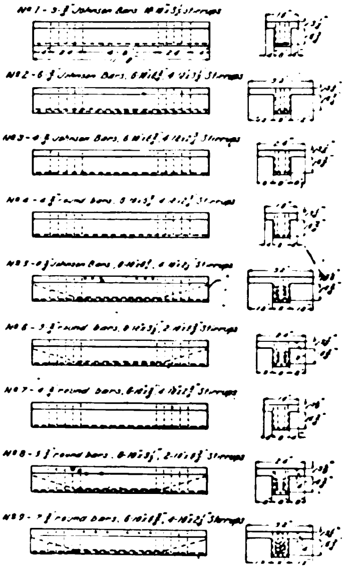


FIG. 8. Arrangement of Reinforcement.

At loads somewhat above the amounts at which it would be expected that failures by diagonal tension in the concrete would occur in beams not having metallic web reinforcement, minute diagonal cracks appeared on the face of the stem in the outer thirds of the span length. These cracks had the direction and appearance of cracks attending failure by diagonal tension. These diagonal cracks generally intersected the plane of the reinforcing bars at their intersection with the stirrups.

All the beams failed by the steel becoming stressed beyond its yield point.

Prof. Talbot calculated the stresses on the reinforcements by the formulæ $f = \frac{M}{0.86\, Ad}$, where f is the tensile stress in the steel, M = the moment of resistance, A = area of the cross-section of the longitudinal reinforcement, and d = the depth from the compressive surface to the axis of the reinforcements.

Professor Talbot states that the formulæ M = 0.86 Afd can be used for the moment of resistance of T-beams for a considerable range of reinforcement.

Table 3 gives the details of the various tests.

TABLE III.

Results of Tests of T-beams.

Beam No.	Flange Width inches	Longitudinal Reinforcement.		Maximum Load pounds			Bending Moment *M* lb.-in.	Stress in Steel *f* lb. per sq. in.
		Per cent.	Kind	Applied	With Beam and Apparatus	Per 8 inches of Width		
1	16	1.05	3 ¾-in. Johnson bars	44 500	46 700	23 350	923 000	64 300
4	16	1.10	4 ¾ in. plain round	29 900	32 410	16 200	631 000	41 500
7	16	1.10	4 ¾ in. plain round	27 300	30 100	15 050	579 000	38 100
3	24	0.93	4 ¾-in. Johnson bars	53 500	55 700	18 570	1 107 500	57 500
6	24	0.92	5 ¾ in. plain round 2 bars bent up	36 800	39 300	13 100	773 500	40 700
8	24	0.92	5 ¾ in. plain round 2 bars bent up	37 300	40 100	13 370	783 500	41 200
2	32	1.05	6 ¾ in. Johnson bars	78 300	80 500	20 120	1 608 000	55 700
5	32	1.05	6 ¾ in. Johnson bars 2 bars bent up (6 transverse bars in flange)	80 800	83 300	20 820	1 658 000	57 400
9	32	0.97	7 ¾-in. plain round 3 bars bent up. (6 transverse bars in flange)	48 100	50 900	12 720	1 004 000	37 600

The full compressive strength of the concrete was not developed when the yield point of the beams were reached. The final deflections of the beams were generally several times as much as those at the yield points, which showed that the elongation of the steel must have caused the neutral axis to rise considerably before the ultimate failure by crushing of the concrete occurred.

This appears to bear out the statement made by Prof. Talbot that beams with 1 per cent. of reinforcement will have only a portion of the compressive resistance of the concrete developed, even when steel of 54,000 lb. per sq. in. yield point is used. The results of the tests showed that the web reinforcement was efficient and adequate.

The diagonal cracks were observed when the value for the vertical shearing unit stress was 180 lb. per sq. in. on an average, and the lowest stress being 147 lb. per sq. in. Without shearing reinforcement diagonal tension failure would be expected to occur when the unit vertical shearing stress was about 120 lb. per sq. in., the higher stress obtained indicates that the stirrups had the effect of resisting the failure by diagonal tension.

TABLE IV. Web Stresses.

Beam No.	Flange Width inches	At First Diagonal Crack			At Maximum Load	
		Load in Pounds		*v* lb. per sq. in.	Bond, *u* lb. per sq. in.	Shear, *v* lb. per sq. in.
		Applied	Including Beam and Apparatus			
1	16	20 000	22 200	161	302	340
4	16	29 900	32 100	234	200	236
7	16	18 000	20 200	147	186	219
3	24	28 000	30 500	222	270	405
6	24	20 000	22 500	164	194	286
8	24	27 000	29 500	214	198	292
2	32	36 000	38 800	282	260	585
5	32	35 000	37 800	275	269	605
9	32	32 000	34 800	253	180	370

Table IV. shows the web stresses attained at the first diagonal crack and at the maximum load calculated by formulæ

$$v = \frac{V}{b'd'} \text{ and } u = \frac{V}{Od'}$$

where V is the total external vertical shear.

b′ is the width of the web, d′ is the distance from the centre of gravity of the compressive stresses to the axis of the reinforcements, and O the total perimeter of the bars.

The values of v obtained for beams Nos. 2 to 5 are several times as great as those obtained for the rectangular beams having no web reinforcements.

The conclusions arrived at by Prof. Talbot from the results of these tests are as follows :—

1.—Beams of flange width of two, three, and four times the width of stem or web and reinforced in each case with steel equal to 1 per cent. of the enclosing rectangle exhibited in a common way the characteristics of rectangular beams, and the critical failure in every case came through the longitudinal reinforcement becoming stressed beyond its yield point.

2.—The full compressive strength of the concrete at the most remote fibre was not developed at the yield point of the beam, even in the beams which were reinforced with steel of 54,000 lb. per sq. in. yield point.

3.—The beams with the wide flanges were deflected somewhat more than the narrower beams, as may be expected from the lack of full width of concrete on both the compression and the tension sides of the neutral axis, the deficiency affecting the stiffness of the beam but having little effect upon its strength at points of maximum bending moment.

4.—The vertical stirrups used proved to be very effective web reinforcement. The diagonal tension cracks appeared at or above the loads at which failure by diagonal tension may be expected in beams without web reinforcement. A high resistance to diagonal tensile stresses was developed, as measured by the calculated maximum vertical shearing unit-stress, which in one beam was 605 lb. per sq. in. Since no beam failed by diagonal tension, the limit of strength of the web reinforcement was not determined.

5.—The observed phenomena of the tests give no indication of distortion from a plane cross section and there was no indication that the thin flange was an element of weakness. The tearing of the flange of one beam after the maximum load was reached was due to causes which would not exist in a floor system as usually constructed. It seems clear that the limit of useful width of flange was not reached in the beams tested.

6.—The maximum strength of T-beams to resist horizontal tension and compression (flange stresses) may well be calculated by using the ordinary methods and formulas in use for rectangular beams and considering the enclosing rectangle of the T-beam to be the equivalent rectangular beam. This approximation is at least applicable for reinforcement not exceeding 1 per cent. of the enclosing rectangle. It gives little error when the thickness of flange is at least one-quarter of the depth of beam and the width of flange not more than four times the width of stem, and may be used for an even greater range without great error. The inclusion of a greater width of flange than four times the width of stem would not materially change the calculated strength of the beam, since the amount of steel which may be put into the stem is usually limited by considerations which of themselves will hold the compressive stresses within proper limits, and since the moment arm of the horizontal couple will not change much with an increase in width of flange. The web stresses, which here are very important, will differ from those found for rectangular beams, and for T-beams the actual width of stem must be used in the calculations for vertical shear and diagonal tension.

Professor Talbot's Experiments on Hooped Columns, 1907. *

These tests, which have recently been carried out by Prof. Talbot, include (1) plain concrete columns; (2) columns reinforced with circular hoops; and (3) columns reinforced with spirally-wound wire.

The concrete used was for the most part 1 : 2 : 4, and the columns were made in galvanised iron moulds, which were kept in place for 10 days.

The columns were moulded on cast-iron base plates, while a cast-iron plate was embedded in plaster of Paris on the top of the columns a few days before testing.

The average age at the time of testing was 60 days. Most of the columns were 12 in. diameter and 10 ft. long, but a few were made 9 in. in diameter.

The hoops and spirals were covered by less than $\frac{1}{4}$ in., so that no complications might arise in the analysis of the strength.

The circular hoops were all 1 in. wide, but three thicknesses were used, their gauges being No. 8, No. 12 and No. 16, or 0·172, 0·109 and 0·0625 in. respectively.

The yield point of the metal was 48,000 lb. per sq. in., and the hoops were electrically welded.

Generally the hoops were spaced 2 in. apart, centre to centre, but in some cases the spacing was 3 and 4 in.

The spirals were No. 7 (0·188 in.), with yield points of 38,000 and 60,000 lb. per sq. in., and $\frac{1}{4}$-in. wire with yield points of 54,000 and 110,000 lb. per sq. in. The two values for the yield points being for low and high carbon steel. No longitudinal reinforcement was used, and the small spacing rods used to hold the hoopings in position was not considered in the calculations.

The percentage of reinforcement was calculated from the volume of hooping to the volume of the concrete core.

---

* *Résumé of a Paper Read by Professor Talbot before the American Society for Testing Materials.*

The average strength of the plain columns was 1,620 lb. per sq. in. with a range of variation of 30 per cent. on either side.

Fig. 3 gives a diagram showing the stress-deformation curves for one of these columns, both the longitudinal and lateral deformations being shown—

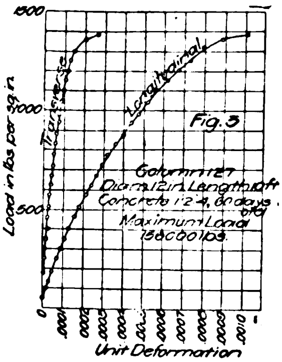


FIG. 3. Stress - Deformation Diagram for Concrete Column.

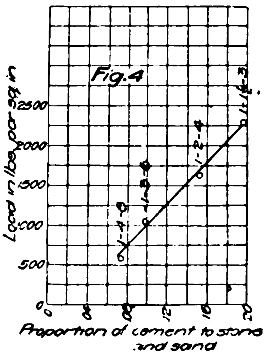


FIG. 4. Effect of Mixture on Strength of Concrete Column.

The ratio of the transverse to the longitudinal deformations averages about 0·1 for the lower loads and rapidly increases near the maximum load to 0·25 or 0·3.

Fig. 4 gives the strength of plain columns made with different proportions of materials in the concrete.

The general phenomena of the tests of hooped columns are as follows. The early part of the test is much the same as for plain concrete columns. At a load equal to that which would cause failure in a plain concrete column or a little above, the concrete over the spacing bars begins to scale, and this is soon followed with a scaling and shelling off of the surface of the column over the hoops everywhere. With added increments of load the amount of shortening increases rapidly and the column correspondingly expands or bulges laterally. The lateral deflection of the column from a straight line begins to be apparent just before the maximum load carried by the column is reached, and it rapidly increases after the maximum load is passed, forming a curve having the characteristics of the figure shown in text-books for columns with fixed ends. The columns finally bent out of line, in some cases as much as 4 or 5 in., the load finally carried being only a small proportion of the maximum.

Figs. 5 and 7 show the stress-deformation curves for a column reinforced with circular hoops and with spirally-wound high carbon steel wire respectively.

These diagrams show that in hooped columns, up to the load where a plain concrete column would fail, the longitudinal and transverse deformations correspond closely with those obtained for plain concrete columns. Beyond this point the longitudinal and transverse deformations increase rapidly.

The total amount of shortening is very considerable, that shown in *Fig.* 5 being more than nine times, and that shown in *Fig.* 7 thirteen times as much as the longitudinal deformation shown in *Fig.* 3.

The lateral deformation in *Fig.* 7 cannot be compared with that in *Fig.* 5, as in the former case the instruments were placed on the concrete between the spirals, which bulged out during the tests.

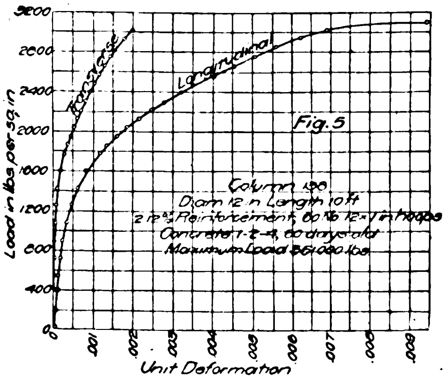


FIG. 5. Stress-Deformation Diagram for Hooped Column.

The results of the tests indicate that the strength of the columns is dependent upon the strength of the concrete mixture, the amount of the hooping reinforcement, and the yield point of the reinforcing. In other words, the additional strength over that of plain concrete columns is a function of the amount and strength of the reinforcing. In *Fig.* 9 are plotted the strength of the hooped columns, and the amount of hooping. The lower line may be considered to represent the strength of the columns with mild steel hooping. Its equation is $P = 1{,}600 + 65{,}000p$, where p is the ratio of the hooping to the concrete core. The upper line is for hooping, having a higher elastic limit. Its equation is $P = 1{,}600 + 100{,}000p$. The columns reinforced with wire having a yielding-point of 110,000 lb. per square inch, gave a still higher strength and, of course, a greater amount of shortening. Equations of the same general nature may be derived from the results of other experiments on hooped columns. The first term represents the strength of plain concrete columns. Prof. Talbot gives these equations tentatively as expressing the results of these experiments.

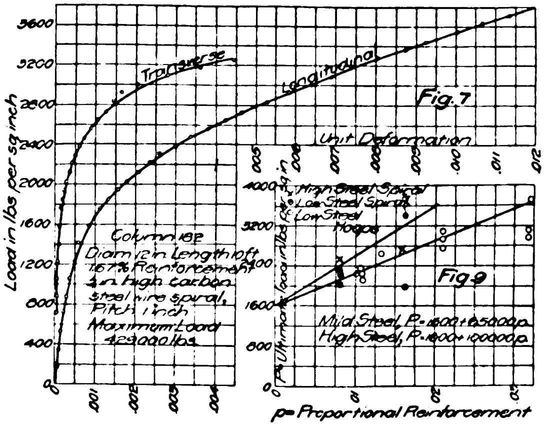


Fig. 7. Stress Deformation Diagram for Column with spiral reinforcement.
Fig 9. Strength of Hooped Columns.

An experiment of some interest was made by first loading a hooped column and then stripping the wire from it and testing the naked column. This column was loaded to 2,000 lb. per square inch, and showed a unit shortening of 0·0036. The load was released and a set of 0·0025 was found. A load of 2,000 lb. per square inch was again applied (the unit-shortening becoming 0·0041) and then released. The spiral was then stripped from the column without taking it from the machine and the naked column failed at 1,080 lb. per square inch. As the indications of the stress-deformation diagram are that the plain concrete would have held 1,200 lb. per square inch on the first application of the load it may be considered that the concrete sustained 90 per cent. of its original strength. The hooped column itself might have held 2,200 or 2,400 lb. per square inch.

Prof. Talbot arrives at the following conclusions from the results of these tests, but states that they are only tentative, and that a further study of the results is necessary before arriving at definite conclusions:—

1.—The ratio of the transverse to the longitudinal deformations for concrete in compression is a variable quantity, increasing considerably just before the ultimate failure of the concrete. A value of 0·1, or somewhat more, may be tentatively given for the lower loads, and 0·25 to 0·3 near the crushing load. This concrete set in air.

2.—In hooped columns the hoops do not come into action to any great extent before a load equivalent to the ultimate strength of plain concrete, or a little below, is reached. The longitudinal deformation and lateral deformation of the concrete are not modified by the hooping to any great extent before this load is reached.

3.—Beyond this point both the longitudinal deformation and the lateral deformation are approximately proportional to the added load. The ratio of lateral to longitudinal deformation is more nearly constant, and in these experiments the ultimate strength of the column is controlled by the elastic limit of the hooping.

4.—The total amount of shortening before failure occurred was very great, averaging something like 8 or 10 times that for plain concrete columns, and 60 times that at the ordinary working stress in plain concrete. The longitudinal shortening is, say, 8 times that of mild steel at its elastic limit. Cracking and peeling of the concrete appear at loads corresponding to the ordinary ultimate strength of concrete.

5.—The excessive amount of shortening before failure affects the problem of combining hooping and longitudinal reinforcement very unfavourably, if the stresses are to be kept within the elastic limit of the latter.

6.—The lateral deflection of hooped columns is large and may affect the ultimate strength which is available for the column. For continued application of stress beyond the maximum load, the column deflects enormously. Scaling of surface of concrete and lateral deflections are warning signs given well before danger of failure exists.

7.—The concrete itself retains a considerable element of its strength even after it has shortened in a hooped state four or five times as much as would produce failure in unhooped concrete columns.

8.—Columns of richer and leaner concrete exhibited phenomena of similar characteristics, the hoop stress becoming effective at the ultimate strength of unhooped concrete.

9.—Hoops of high elastic steel give greater strength than of mild steel, but the increased amount of shortening necessary to develop the full strength of the column is an undesirable feature.

10.—One experiment indicates that hooped columns will resist eccentric stresses in somewhat the same way as will other material.

11.—Light hooping offers security against sudden failures and unevenness of concretes, and will enable higher working stresses to be used. In combination with rich concretes and longitudinal reinforcement, using low stresses in the hoops, *i.e.*, basing the strength upon an assumed ultimate strength but little beyond the average ultimate strength of plain concrete, a satisfactory column may be made. It is suggested that a column of this character may be designed in such a way that the longitudinal reinforcement may carry the load during construction and still not be overstressed later for the additional stress which goes with the concrete, provided the basal point for the column strength is somewhat below the ultimate strength for plain concrete.

12.—Heavy hooping gives added strength, but in utilising the full strength of such columns the column shortens unduly, deflects laterally, and will strain longitudinal reinforcement many times beyond the deformation which exists at the elastic limit of the metal. It may be applicable where a large limit of safety is desired, or where large variations in shortening are unobjectionable, as where the structure is articulated. So far as ultimate strength is concerned, hooping adds two to four times as much strength to the column as does an equal amount of longitudinal reinforcement.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Special Commission on Concrete Aggregates.—The work of the Special Commission on Concrete Aggregates recommenced last month for the winter session. The Test and Research Committee, under the chairmanship of Mr. W. T. Hatch, M.Inst.C.E. (Chief Engineer Metropolitan Asylums Board), is meeting frequently to settle the procedure of the tests necessary for arriving at reliable comparative results with the different concrete aggregates. It is expected that the series of tests will be a protracted one, involving more than a thousand test pieces. The Specification Sub-Committee, under the chairmanship of Mr. Max Clarke, F.R.I.B.A., has likewise again met for consideration of the correct specification of aggregates in use.

It is interesting to observe that at the request of Sir William Preece, K.C.B., M.Inst.C.E., chairman of the Special Commission, contributions towards the expense of the Commission have been received from the Portland Cement Industry, the list of subscribers being headed by the Associated Portland Cement Manufacturers (1900), Ltd., with a hundred guineas. Nearly £175 have already been promised by the industry in question. The concrete trade will, no doubt, soon follow suit, as the results of the enquiry closely concern them.

The R.I.B.A. and Reinforced Concrete. — A request for information of no small importance to the advancement of reinforced concrete has reached the Royal Institute of British Architects from official quarters, and we understand that the reply has been a favourable one.

Mr. Edison's Ideas of Concrete Building as dealt with by "Punch."—The following appeared in *Punch*, based upon some amusing passages in the daily Press, recording the alleged announcement attributed to Mr. Edison as to using liquid cement for model houses :

[*Mr. Edison has re-invented an old method of building houses. Liquid cement is poured into iron moulds, and when the cement sets the moulds can be taken away, leaving a strong building. A three-storey house can be built in 24 hours at a cost of £200.*]

Mr. Punch's View.

Mr. Edison's announcement, while paralysing the building trades, has stimulated activity in other quarters.

The more extravagant party in the London County Council talk of laying liquid-cement mains in Suburban London. It would be a great boon, they argue, to the ratepayer to be able to turn on the cement, just as nowadays he turns on the water for the garden hose. If unexpected guests come for whom there is no room in the house, if a fowl-house or dog-kennel should be required, if the householder has ambitions towards a billiard-room, if a porch or conservatory, or even a summer-house, should need to be built, if the roof begins to leak in a storm, or (as in some cases it has done) becomes restless, if the garden wall must be raised to keep next-door from staring—in fifty different emergencies a ratepayer would find an ever-ready supply of liquid cement most useful. All he would have to do would be to send down to the local ironmonger for the moulds, stick them up, and then leave the tap running into them, with perhaps the youngest boy to keep an eye on it.

We should like to suggest that the cement tap ought to be coloured red, so that it be not confused with the water tap. Cement, however liquid, is not a good thing to water the garden with or to boil the potatoes in.

A noble lord who is an intimate friend of ours informs us that peers generally welcome Mr. Edison's invention. They feel they can now snap their fingers at Sir Henry Campbell-Bannerman. What if he does abolish the House of Lords, they say. With Mr. Edison's help they can build a new one any week-end.

Mr. Edison's Explanation.

There is no doubt that Mr. Edison's proposals, whatever they may have been, were regarded in this country as somewhat confusing, but we have before us a letter from Mr. Edison to a correspondent on the subject, which we give below, but which we are afraid does not do much to elucidate his intentions, beyond explaining that he considers them to be of a "humanitarian character." Mr. Edison writes:

> I am in receipt of many letters regarding newspaper articles describing a cement house which I am about to erect. The writers of most of the letters have misread the articles, and I take this occasion to explain what I propose to do. I now have a model, one-fourth the size of the house, designed by the New York architects. This winter I shall construct the iron moulds and devise machinery whereby a full-sized house can be cast in 12 hours after the moulds are in position. At the end of six days the iron moulds are removed, and the house will be complete, including stairs, partitions, mantels, bath, etc., and after drying six days will probably be ready for occupancy. To build this house for $1,000 it is essential that it be erected on sandy soils, as the material excavated for the cellar is all that is required to build the house, except, of course, the cement. The cost of the iron moulds will be about $25,000, and the cost of the other machinery about $15,000. From this outfit an unlimited number of houses can be erected. It is probable that companies will be formed, who will have several moulds, each of a different design, and will go actively into business. I have not gone into this with the idea of making money from it, and will be glad to license reputable parties to make moulds and erect houses without any payments on account of patents, the only restriction being that the designs of the houses be satisfactory to me, and that they shall use good material. —Yours very truly, THOS. A. EDISON.

Wooden vs. Concrete Bridges.—The county commissioners of Pueblo County, Colorado, have decided to take out all the wooden bridges in the county and replace them with reinforced concrete and cement structures. The commissioners reached this decision after an inspection of all the bridges and culverts in the county. They believe that the new and more substantial structures can be erected at practically the same price as was paid for putting in the wooden bridges, and that they will not only be better and safer, but their installation will do away with the great amount of repair work that has been necessary on the structures that are in service now and which have been used for a number of years.

Old Country Bridges: Their Preservation by Patent Cement Grouting.—We feel sure that our readers will be interested in the suggestion put forward by Canon Rawnsley, in a letter which appeared in a well-known daily some time back.

Canon Rawnsley writes:

> I have lately had the pleasure of hearing the opinion of the well-known engineer, Mr. Francis Fox, upon the possibility of saving from destruction certain interesting bridges in th. Lake District, and it seems to me that the method he suggests for converting such picturesque structures, at a comparatively small cost, into what can only be described as a condition of monolithic strength, without interfering in any way with their beautiful lines, is one that must commend itself to ratepayers and bridge authorities throughout the land.
>
> Owing to the increase of the motor and traction-engine traffic many bridges have lately shown signs of cracking. In such a case the first thing the ordinary bridge surveyor does is to declare the bridge unsafe; the next thing is to prepare plans for the demolition of the old picturesque structure and the erection of a common-place, unpicturesque, flat-arched bridge in its place.
>
> The ratepayers are helpless, they know nothing of any other means of procuring safety for the condemned bridge than the entire rebuilding of it. The bridgemasters are only human, and like a chance of showing what they can do; the highway authorities are able to silence any outcry on the part of the public by saying that since their surveyor has condemned the bridge they have no alternative but to pass plans for the erection of a new one.
>
> But if the public authorities knew that by the use of a very simple machine invented by Mr. James Greathead, called the grouting-machine, and the help of a couple of masons and a few tons of cement, the broken bridge, cracked arch, shaken pier, or tottering parapet could be rendered solid as rock, and the structure made serviceable for generations at one-tenth the cost of rebuilding, and at immense saving of time, they would probably insist, to the satisfaction of the ratepayers, that our beautiful countryside bridges should be saved, and not replaced, at the call of the motor-car or traction engine, by the costly ugliness of the twentieth century.
>
> The "grouting-machine" is simplicity itself. It consists of a cylinder which is used like a barrel-churn to work up Portland cement, sand, and water to the consistency of thick

cream, and a second cylinder of compressed air for blowing this "grout" through a hose and nozzle into the cracks and interstices of the masonry, till the interior of the structure is permeated with the material, which quickly sets and gives to the whole mass homogeneity and solid strength.

Addenda. — On page 398 of our last issue we presented some additional views of the Lilburn and Lucker Bridges, a full description of which was published on pages 425 and 426 of our No. 6, Vol. I., issue. It was stated that the bridges were tested in the presence of Mr. Harry W. Taylor, A.M.I.C.E., Engineer to the British Concrete Steel Co., of Newcastle-on-Tyne, who constructed them. We omitted to mention that the bridges had been designed on the Kahn system.

Reinforced Concrete Groynes vs. Timber Groynes.—The recent injury to Ventnor Pier by the wreckage of a timber groyne dashed against the cast-iron columns affords one more instance of the disadvantage of timber for marine structures. Apart from the certainty of decay and destruction by wood-boring sea worms, timber suffers from the drawback of being lighter than water, and therefore when used in groynes must be fixed very securely to prevent displacement. Even then there is always the risk that fastenings may fail, and that, as actually happened at Ventnor, the groynes may be swept away by heavy seas to work havoc on other structures. It is indeed strange that people persist in the use of timber for the construction of groynes when they have in reinforced concrete a far more suitable and, considering all things, a less costly material, immune from the attack of sea worms, not liable to decay, and much heavier than water. If the authorities at Ventnor had followed the lead of the Sussex County Council, the Brighton Sewers Board, and the Rottingdean Improvement Commissioners, by building their new groyne of reinforced concrete, they would not now be regretting the fact that a large portion of the work, which cost £800 only a short time ago, was carried away and used as a battering ram against the neighbouring Pier.

Concrete Bags in Sea-Work.—An interesting communication from the pen of Mr. Wm. Dyce Cay, M.Inst.C.E. Edinburgh, was published in *Engineering*, on the subject of concrete in bags in sea-work. The letter reads as follows:

Building with soft concrete in mass is a necessity for harbour authorities who have not the means necessary for constructing what may be called monumental works, such as breakwaters built of Cyclopean blocks, faced with granite, requiring expensive machinery and plant. And it has the advantage that very large masses or blocks can be moulded *in situ*.

To produce satisfactory concrete work below water in this method, it seems to me of great importance that the concrete should be got into place in as nearly as possible the same condition as when it left the mixer. That is the object of the enclosing bag, which keeps out the sea-water. Of course, no time should be lost between the mixing and the deposition. There must be large mixing power, the cement and aggregates must be collected close to the hoppers of the mixers, and large wagons or tubs used to transfer the concrete to the box in the hopper barge, in which the bag has previously been placed; the barge should be rapidly taken to the site of deposit, the bag being sewn up during the transit; and when brought into its true position, the pulling of a trigger releases the doors of the box, and the bag falls slowly through the water to its place.

There is nothing in the above system to prevent satisfactory execution, and in point of fact, so far as this part of the work goes, with me it never failed. We put in a maximum of, I think, nine blocks a day, of 50 tons each, at Aberdeen north pier in summer, and probably the time occupied from mixing to depositing was half an hour, during which time the bag was partly under water, owing to the increased draught of the loaded barge, so that there would not be much preliminary setting.

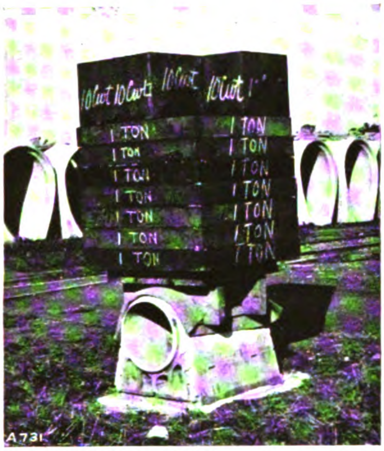
We did not dump a fresh bag on one recently deposited; on the contrary, we carried out each course for a considerable length of time before commencing the one above it, the position of each bag being set out from a plan prepared beforehand.

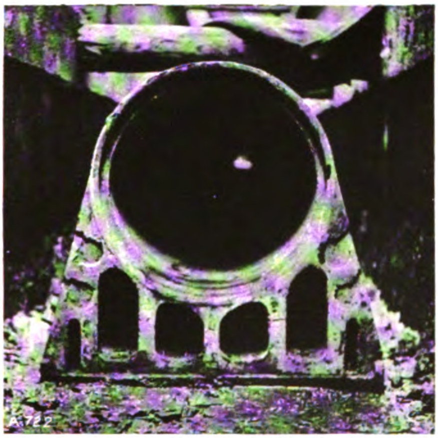
The longitudinal axis of each bag was placed above the meeting edges of the two below it, so as, with the assistance of the softness of the material, to have no crevices or daylight between them.

With regard, however, to the choice of suitable situations for the use of the system, engineering judgment must be used. I found it very suitable for levelling the foundation, in the boulder clay bottom, of the new south breakwater at Aberdeen, before founding the concrete blocks, of which the part below low water was built; also for forming an apron to the same work of 100-ton bag-blocks: also for building the whole of the North Pier extension there, up to above low-water level. The Lerwick Pier Works I built in the same way, and recommended it for the Newhaven (Sussex) breakwater, where it was used. The Fraserburgh, Burghead, and Sunderland works all used the barge I designed, but I am not aware of the engineering features of the works. It is plain that a face built with bags, the ends more or less regularly projecting, would not be suitable to receive heavy broadside seas. This may account for some failures.

I may add some remarks on ordinary concrete-in-mass building in the sea. Referring to my remarks above, as to the desirability of getting the concrete into its place in the same condition as when it left the mixer, at the South Breakwater at Aberdeen I founded the mass on the blockwork, about 1 ft. above low-water of neap tides by enclosing the space with shuttering lined and carpeted with jute cloth. Commencing at low water, when the bottom was dry, I carried the filling up quicker than the tide rose, so that the sea-water did not penetrate the mass. This produced very strong work. The same system of lined shuttering has since been followed in other places where the mass is founded below low water. Here, of course, the concrete must, more or less, pass through the sea-water in its transit from the mixer to its site. The damage which would be produced is met by using very large skips—say, holding 6 to 9 tons each—for the depositing, also by using a much larger proportion of cement. The great size of the skipfuls deposited at a time allows most of the concrete to pass through the water undamaged, and the larger quantity of cement used allows for the wastage which appears in the formation of "laitance." This system, as indicated in Mr. Austen's article, has been found useful for fishery harbours, and is well known.

Reinforced Concrete Docks and Wharves at Venice.—We observe with considerable interest that the Docks Cotoni Co., of Italy, have decided to build docks and warehouses on a large scale at Venice, and that reinforced concrete is to be used throughout. The warehouses are to be designed to hold 400,000 bales.





Reinforced Concrete Sewers at Great Crosby.

Reinforced Concrete Sewers.—In our last issue, November, 1907, we referred to the new sewers being constructed for the Urban District Council of Great Crosby under the supervision of Mr. Watkin Hall, surveyor to the county, and we are now informed that in addition to the "Aqueduct" invert blocks already used, they have also constructed a tributary 18-in. pipe sewer, composed of reinforced granite concrete.

The design of same is based on the equilateral principle, thus securing solidity of base, while due provision is made for dealing with subsoil water. The pipes and base interlock in a similar manner to the blocks.

The two photographs here presented show one of these pipes under a test load of 10 tons, and a length of pipe laid at the bottom of a trench. These pipes are also manufactured by Messrs. John Ellis & Sons, Ltd., of Leicester, as a speciality.

In view of the many defects and failures of the ordinary stoneware pipes to stand the pressure in certain classes of ground, irrespective of the exact form of jointing used, it is suggested that these new pipes are likely to meet the requirements of many engineers who have difficult ground to deal with, possessing as they do the novel features of solidity of base, watertight joints, and due provision for dealing with the subsoil water without interference with the actual sewer.

Reinforced Concrete Towers.—The Lincoln Light and Power Company have recently erected in the Province of Ontario reinforced concrete towers which are the highest monoliths in existence. These towers are 150 ft. long and 142 ft. above ground. They are 31 in. square at the base and 11 in. square at the top, and carry cross-arms for the electric service wires. The towers were moulded in a horizontal position, and then raised into place by wooden shear legs after being allowed to harden for more than a month. The concrete was composed of one part of Portland cement and five parts of sand and gravel, and four reinforcing steel rods, one at each corner, take the tensile stresses due to wind pressure and pull of the wires.

Waterproofing Concrete. — The British Commercial Agent in the United States reports to the Board of Trade that attention has lately been called both in the technical and daily Press of that country to a new process by which concrete is said to be made practically waterproof. "The method of doing this, which appears to be both simple and effective, consists in adding a small amount of ordinary clay to the cement; it is claimed that this not only renders the concrete impervious to water, but also strengthens it. Ordinary concrete is porous, and vast sums have been expended from time to time in the endeavour to make it waterproof. Now that reinforced concrete is being so largely used, it is evident," Mr. Bell observes, "that any practical method of preventing water from reaching the steel rods embedded in the cement would be of the greatest value."

Liverpool Building Regulations. — We are pleased to observe that the Corporation of Liverpool is applying for powers to modify the provisions of the Act regulating the construction of buildings in the city, where the provisions as to ordinary building materials are not applicable, as one instance, in the case of the use of reinforced concrete.

Concrete Models or Maps. — A large map or model of the Panama Canal has been recently completed, with a view of presenting a true picture of the district through which the canal passes. The dimensions of this model are no less than 122 ft. by 50 ft. It was on view at the Jamestown Exhibition.

The idea of a model or map in concrete should frequently be useful where large engineering works are concerned, and there is no doubt that a large model of this description should be of great assistance in supplementing the sets of plans where the work has to be described to a board of lay directors, or others not technically conversant with engineering works.

Lectures on Reinforced Concrete at Liverpool and Leicester — "Reinforced Concrete in its Practical Applications" is the title of a paper read before the Leicester and Leicestershire Society of Architects by Mr. Moritz Kahn, on November 13th, the discussion on the paper being opened by Mr. Howard Thompson, F.R.I.B.A., president of the Society. The paper was illustrated by lantern slides.

Another paper, entitled "A Review of Reinforced Concrete—its Theory and Practice," was read by Mr. Kahn before the Liverpool Engineering Society, the principal argument in which reads as follows:

> Experience led to the conclusion that reinforced concrete was the best form of construction when properly handled, and the worst when improperly handled. Such being the case, it behoved the owner, or engineer, to ensure that only the best class of contractor was employed upon his construction work. Any desire to reduce indefinitely the cost of construction by unlimited competition should be avoided, as it was undesirable that any but reliable contractors should be employed. Such a one could only afford to carry out work which would assure him a fair amount of profit, and it was only the unreliable contractor who could secure profit out of cheap construction, which he did by scamping the work.

Applications of Reinforced Concrete to Engineering Construction. — On November 6th, Mr. J. S. E. de Vesian, M.Inst.C.E., read a paper before the Civil and Mechanical Engineers' Society on the above subject. The reader of the paper, who has had considerable experience of reinforced concrete work, treated the subject from the practical standpoint. He pointed out the importance of using steel of suitable quality. With regard to the economy of reinforced concrete construction, the author quoted several instances where the capital outlay was reduced by several thousand pounds by the adoption of reinforced concrete.

Exterior Treatment of Concrete.—Mr. J. Henry Sellars recently presented a paper before the Manchester Society of Architects on the Decorative Treatment of Reinforced Concrete Buildings, and drew upon various historical examples of the simple treatment of flat surfaces, as also their treatment with mosaics, tiles, etc.

Catalogues.—The Patent Indented Steel Bar Co., Ltd., of Westminster, have sent us a descriptive catalogue of ninety-two pages of well-illustrated matter, dealing with their system of reinforced concrete construction. The catalogue is an improvement on their previous issues, inasmuch as it does not contain unnecessary complicated algebraical formulæ.

Of the numerous illustrations presented, those of Downside Reservoir, Somersetshire, are probably the most interesting to our readers from a technical point of view. A somewhat special feature is the illustration of several concrete cottages at Evesham, in which the "Indented" bars have been used.

The catalogue, which is obtainable at the company's offices, Queen Anne's Chambers, Westminster, is certainly one of the best we have seen of late.

L. G. Mouchel & Partners, Ltd.—The announcement has been made that Mr. L. G. Mouchel, the agent for the Hennebique system in this country, will henceforth conduct his work under the above description, the capital of the company being £50,000 in £1 shares. The first directors are Mr. L. G. Mouchel, J. S. E. De Vesian, and Mr. A. T. J. Gueritte, the remuneration of the directors being, except the managing director, £1,800 per annum, 5 per cent. of the gross profits, and any further remuneration the shareholders may vote. The object of the company is described as being to carry on the business of specialists in "ferro-concrete" construction, engineers, architects, etc.

The new company owns the goodwill and so much of the business of Mr. L. G. Mouchel as was carried on at 38, Victoria Street, and elsewhere, and was not connected with the Hennebique agency, certain leaseholds, furniture, instruments, patents, and the benefit of all contracts pending as from July 1st, 1907.

The consideration paid therefore was in part by the allotment of 30,000 fully-paid £1 shares and the issue of a £10,000 first mortgage debenture.

The shareholders comprised on the 1st of December: R. E. de Vesian and F. Geoghegan (jointly 20,000); L. G. Mouchel (14,000); J. D. E. de Vesian (3,000); A. T. J. Gueritte (3,000).

The company was registered by Ellis de Vesian & Co., Solicitors, Old Jewry, E.C.

New Contracts. – The United Kingdom Fireproofing Co. have secured the contract for the steel-work, floors, roofs and partitions of the three telephone exchanges at Manchester, Glasgow and Dalston. This company's system will also be used for the floors and roofs of the Kingsway Bank, and for the floors, roofs and staircases of the new chemical laboratory at Cambridge.

NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

REINFORCED CONCRETE TELEGRAPH POLES.

By G. A. CELLAR.

PROBLEMS confronting those who first undertook the manufacture of concrete poles without any precedent to guide them included the following:—

(1) Shall the poles be made of such dimensions as to necessitate a concrete foundation, or of such size and shape that they will be securely held in ordinary earth by thorough tamping?

(2) Shall they be made in a yard and then distributed, or shall the material be transported to the various locations in which the poles are to stand and the poles be made there?

The experience of late years on all lines of railroad is that the expansion of track and other improvements have made it necessary to move to new right-of-way lines so many telegraph poles that, in planning for a pole of infinite life, it would be better, if possible, to procure a type which would be secure without the foundation which would render its location when once set up a permanent fixture, and this type would be preferable to the fixed type.

(*a*) Because of its smaller cost to construct;

(*b*) Because of its smaller cost to set up in the line, and

(*c*) Because it will be easily removable to a new location.

The second question was decided in favour of the manufacture of poles in yards, because their construction at the points at which they are to be set involves the transportation to these points of not only the solid materials to be used in their manufacture, and shelter for these materials, but also the water, which is not ordinarily available, and the forms. In fact, a very considerable additional physical property in the crude materials proportionate to the smaller sum total of the finished product.

On busy railroads construction at the point of setting would involve the assembling of the apparatus on a car, the use of motive power and the obstruction of the main track to a certain degree. This being the case, the alternate plan does not require any more apparatus or crew, will not require the services of a locomotive and crew as long or for any longer time than the plan of making the poles at the place where they are to be set up; but it involves in addition, perhaps, the use of a derrick to be mounted on a car, the beam of which shall have sufficient radius to reach the line on which the poles are to be set. The procedure to be followed would then preferably be to manufacture the poles in a yard and have them thoroughly seasoned there before moving. In preparing for distribution, they should each be tagged or otherwise have a designation or location attached to each one, indicating the exact site in which the surveyor or inspector has designated each to be set on account of the necessities for grading the line. The poles should then be loaded by the use of the yard derrick or a derrick car, be taken out by a train, and by the crew of the derrick set up in their permanent places in the line, in holes previously dug for their reception. This plan will require very little if any more obstruction of the main track than the stoppages requisite for the unloading of seasoned cedar poles.

In the working out of the plans for the requisite strength with the minimum of weight, the two hollow poles referred to in detail hereafter were made. The results of the tests are given in this paper, as an example of progress and are not to be taken as the best form for adoption, but quite the contrary. One of the patterns was square in section, with the corners chamfered off; the other, octagonal in section, and the hollow space extending from the base for about two-thirds of the length of the pole, the upper third being solid, and the walls of the lower two-thirds being from 1¾ in. to 3 in. thick. These poles weighed approximately 3,500 lb., and were calculated to withstand any stress in any direction that could possibly be imposed upon them by a line of fifty wires, each wire coated with sufficient ice to make it 1 in. in diameter. The test was made in connection with two carefully-selected cedar poles of the same length (30 ft.), and all were set in concrete, the bases being 3 ft. by 3 ft. by 5 ft. deep.

Just within the outer surface the walls of the concrete poles were reinforced with iron rods, which consisted of four ¾-in. round bars, each 24 ft. long, and four ⅝-in. round bars of the same length. The poles were 8 in. in diameter at the top and 13 in. at the base, having a taper of 1 in. to each 5 ft. Galvanised iron steps were screwed into wooden blocks moulded into the concrete, and holes were left for through bolts for supporting the cross-arms. The cross-arm braces were attached to the arms by through bolts in the same manner and fastened to the poles with ordinary lag bolts driven into wooden plugs, which were placed in the concrete at the proper places. The concrete poles were set to a depth of 5 ft. in concrete with the two white cedar poles of practically the same dimensions, and, after standing long enough to permit the cement to become solid, they were tested in turn in the following manner:—

An iron clevice was placed around the pole to be tested 10 in. from the top, to which a wire rope was attached, leading over a pulley placed at the same height and at an equal distance from the pole, so as to form a right-angle, and fastened to a differential pulley-block, which was attached to a laboratory weighing machine.

The results are fully shown in following tables, and in the accompanying diagrams and illustrations made from photographs:—

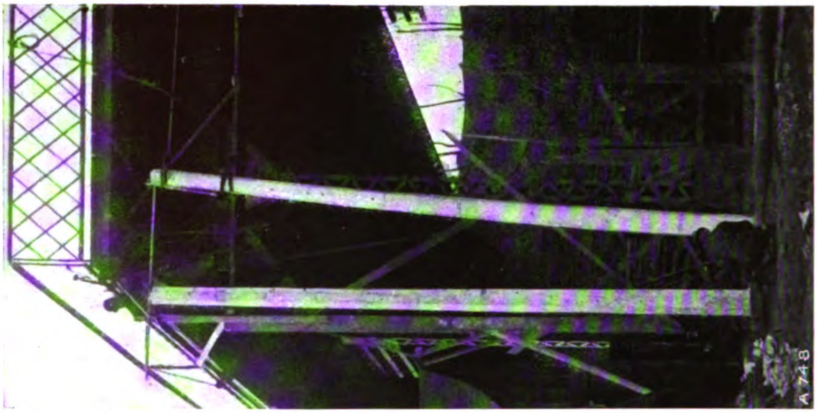
RESULTS OF TEST ON POLE NO. 4. WHITE CEDAR.

Length 30 ft.	Base Diameter 14 in.	Top Diameter 8 in.	Depth in Concrete Anchorage. 5 ft.	Distance from Point of Fulcrum to Point of Load. 24 ft. 2 in.
Deflection at Top.	Load Pounds.			Time.
20 in	1,830			11 : 50
22¼ in.	2,230			11 : 51
29 in.	2,630			11 : 52
35 in.	2,870	First crack		11 : 53
36½ in.	2,950			11 : 54
38½ in.	3,030			11 : 55
50 in.	3,370			11 : 56
56 in.	3,430			11 : 57
65 in.	3,494	Pole broke		12 : 00

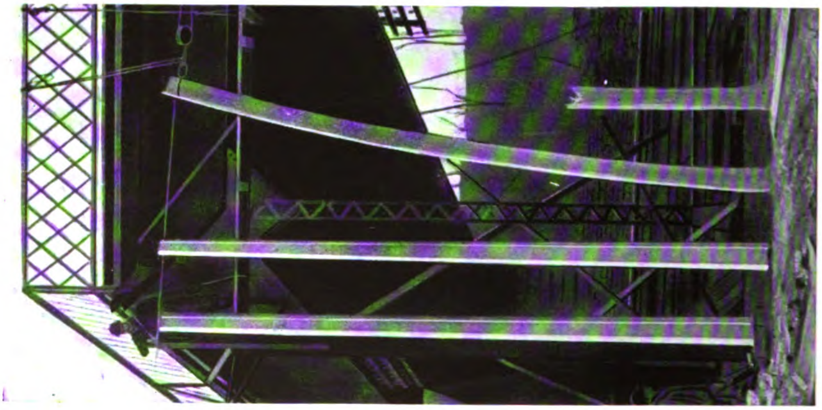
After the cement poles had been broken the reinforcement so held them that it required almost the breaking pressure to further deflect them from their slightly inclined position. The wooden poles, under strain, presented the form of an arch before breaking, and when they gave way they were fractured completely; but these features were lacking in the cement poles, which were very firm and did not give until they began to crush at the ground line.

The mixture used in these cement poles was 1 : 3. They were constructed in cold weather, and, through some mischance, at the last moment we were unable to get suitable gravel. Pole No. 1 was found to have a defect in the casting, which is believed to be the cause of its early rupture. Pole No. 2 gave a very much better result.

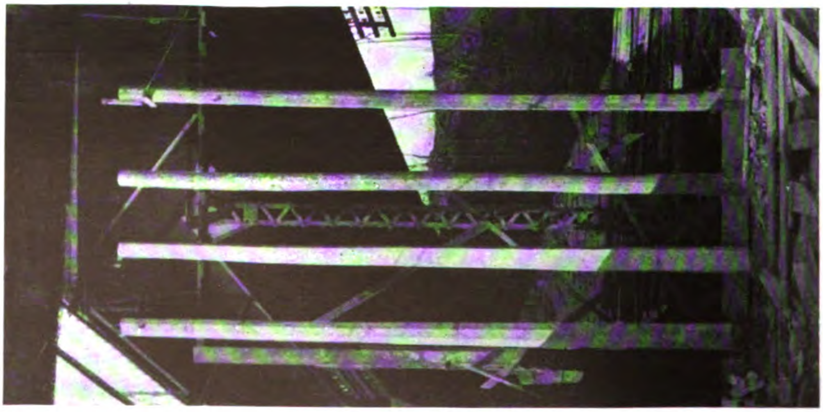
The consensus of opinion seems to be that a 1 : 2 : 4 mixture is the best for use in this class of construction, and, while the experiments referred to were entirely satisfactory in the development of the problem, the hollow pattern is not considered to be the highest type desirable; that is, to combine sufficient strength with the least



Square Reinforced Concrete Pole. Test No. 3.
Just before crack No. 1 (Pole cracked at deflection of 34½ inches).



Wooden Pole. Test No. 2.
Deflection 56 inches (Pole broke at deflection of 66 inches).



The Poles as set.

RESULT OF TEST ON POLE NO. 3, WHITE CEDAR.

Length	Base Diameter	Top Diameter	Depth in Concrete Anchorage	Distance from Point of Fulcrum to Point of Load.
30 ft.	14 in.	8 in.	5 ft.	24 ft. 2 in.

Deflection at Top.	Load Pounds.		Time.
14 in.	172		......
37 in.	2,230		......
47 in.	2,530	Po'e broke	11 : 03

possible weight, in order to obtain ease in handling, and that the removal from place to place may be readily feasible.

To fulfil these requirements the pole should be made with a superstructure of somewhat greater strength than the wires which it is required to support, joined to sufficiently added strength by reinforcement and added area in the base, especially at the ground line; and the base should be reinforced in the most effective way to withstand the extreme pressure at the point of fulcrum.

These conditions are all capable of mathematical computation, and if fulfilled will give a product comparatively easy of manufacture, of reasonable cost, of greater tensile strength than the poles now in use and extremely high durability.

The argument has been advanced that the reinforced cement pole would be very liable to damage or disruption by shock, but the fact that concrete piles, both of hollow and solid designs, are driven by pile drivers, and especially with the knowledge of the experiments at Rochester, which showed that the poles, even after they had been fractured at the surface of the foundations, required an extremely heavy pressure to produce further deflection from the positions at the time of fractures—in other words, that they were almost as stiff as when they stood upright, and continued to be so throughout the entire test—I feel that any alarm at the prospect of damage by collision between the pole and anything else than a movable object that would destroy any pole of natural or manufactured composition is unfounded.

RESULTS OF FOUR TESTS ON POLE NO. 2, CONCRETE, SQUARE.

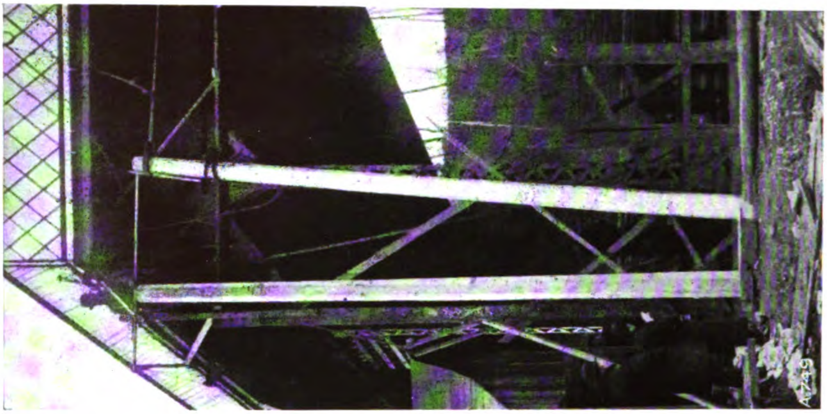
Length.	Base Diameter.	Top Diameter.	Depth in Concrete Anchorage.	Distance from Point of Fulcrum to Point of Load.
30 ft.	13 in.	7 in.	5 ft.	24 ft. 2 in.

Deflection at Top.	Load Pounds.		Deflection 12 inches above Ground Line.	Time.
		TEST NO. 1.		
¾ in.	50		....	2 : 02
2¼ in.	1,830		....	2 : 04
3½ in.	2,230		....	2 : 08
		TEST NO 2.		
¾ in.	50	Temporary deflection	1 in.	......
4 3/16 in.	2,630		....	2 : 10
8½ in.	3,030		1/16 in.	2 : 11
		TEST NO. 3.		
3½ in.	50		....	......
31 in.	3,290		....	......
34½ in.	3,430	Crack No. 1	⅛ in.	2 : 14
		TEST NO. 4.		
21¼ in.	50	Temporary deflection	22 in.	......
39 in.	3,690	Crack No. 2, 3 and 4, Pole crushed crack at ground level.		

As to the insulating qualities of the concrete pole, it is hardly necessary to mention that they are superior to those demonstrated in any other pole manufactured in this country.

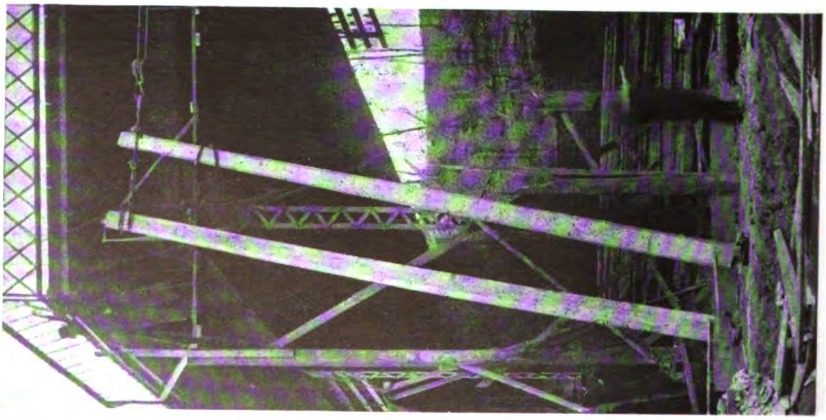
The writer has collected the following references to work done by others on concrete poles, which may be interesting to those who wish to trace the progress of this line of experimenting.

The "Geological Survey of Ohio," fourth series, Bulletin 2 (1904), entitled "Uses of Hydraulic Cement," by Prof. Frank Harvey Eno, of the Ohio State University, presents in an article, entitled "Cement Telegraph Poles," an item of some interest, describing cement butts for wood poles that have rotted off, observing that when a pole has to be replaced often only the part setting in the ground has deteriorated, and while in some country districts the pole may be cut off and reset there are many poles that must be replaced altogether, thus losing the most of the pole. To meet this contingency a cement base has been devised, octagonal in shape, with four iron strips bolted to opposite faces, extending a foot or more above the concrete. In installing this concrete base the rotten pole is sawed off, the lower end swung a little to one side, the cement base put in the place of the rotten stump and

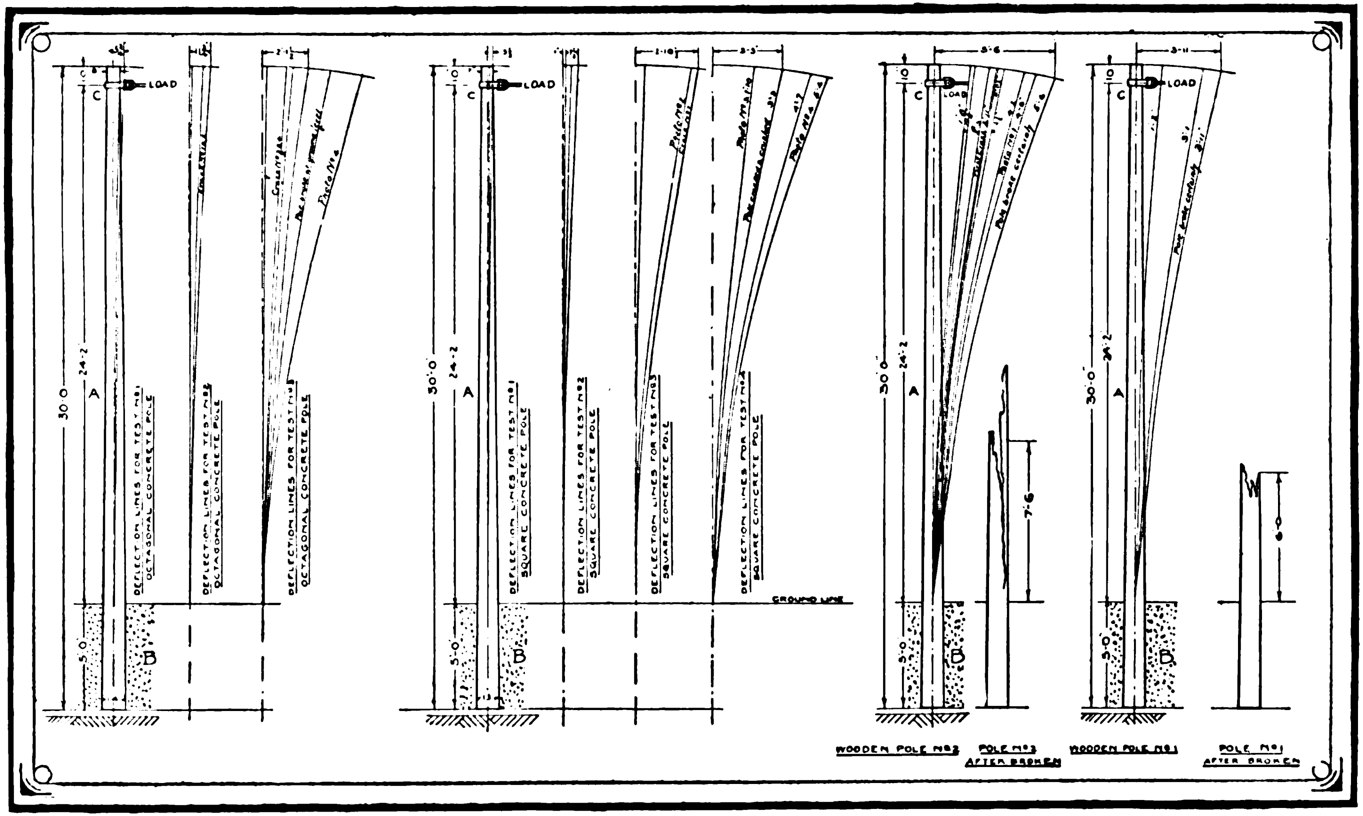


Square Reinforced Concrete Pole. **Test No. 4.**
Deflection 64 inches.

Square Reinforced Concrete Pole. **Test No. 4.**
Deflection 22 inches.
(Pole **cracked** and crushed at ground **level** at deflection of 39 inches.)



Octagonal Reinforced Concrete Pole. Test No. 3.
After Pole broke.
(Pole broke at ground level at deflection of 25½ inches).


LOAD
A
B
C
30'0
24'2
5'0
1'0
DEFLECTION LINES FOR TEST No1 OCTAGONAL CONCRETE POLE
DEFLECTION LINES FOR TEST No2 OCTAGONAL CONCRETE POLE
DEFLECTION LINES FOR TEST No3 OCTAGONAL CONCRETE POLE
DEFLECTION LINES FOR TEST No1 SQUARE CONCRETE POLE
DEFLECTION LINES FOR TEST No2 SQUARE CONCRETE POLE
DEFLECTION LINES FOR TEST No3 SQUARE CONCRETE POLE
DEFLECTION LINES FOR TEST No4 SQUARE CONCRETE POLE
GROUND LINE
2'1
1'10
3'3
3'6
3'11
7'6
6'0
WOODEN POLE No2
POLE No2 AFTER BROKEN
WOODEN POLE No1
POLE No1 AFTER BROKEN

Diagrams Showing Character of Deflection of Poles at Intervals in the Series of Tests.

Experiments with Reinforced Concrete Telegraph Poles.

the pole is then swung into the socket formed by the iron strips and securely bolted. The pole when thus equipped is alleged to be better than new. In restumping in the manner just outlined no wiring need be touched nor telegraph communication interfered with in the least. Another feature of the use of these cement butts is that when a pole has deteriorated beyond the point of usefulness and has to be replaced a pole 5 ft. shorter can be furnished, thus materially reducing the cost. The above-mentioned article states that these butts had been in use for three years and were giving good satisfaction. The practice of restumping is largely followed in the present day, except that stumps of wood are used instead of those of concrete.

The *Cement and Engineering News* for August, 1902, mentions with strong approval the cement butts manufactured at Battle Creek, Mich., giving about the same points stated above and estimating that a saving of from 35 to 55 per cent. is realised by the use of these butts in reconstruction.

Mr. Robert A. Cummings, member A.S.C.E., a consulting and constructing engineer, with offices in Pittsburg, Pa., made, in 1903, some experimental concrete telegraph poles at Hampton, Va., and found them to be quite satisfactory for ordinary purposes. The cross-section was that of an equilateral triangle with 12-in. sides at the bottom of the pole and 6-in. sides at the top. The poles were 30 ft. long and were reinforced with ¾-in. vertical rods at the corners. They were stiff enough to support their own weight, a span about 20 ft. At that time Mr. Cummings had not seen any concrete poles in actual use, but said he had designed some large distributing poles for the New York Telephone Company.

Mr. McDonald, chief engineer of the Nashville, Chattanooga and St. Louis Railroad Company, wrote under date of January 22nd, 1906, that he had used concrete poles 5 in. square at the top and 8 in. at the bottom, 30 ft. long, for supporting warning straps, or ticklers, and that they have given such satisfaction that he has adopted them as standard for that purpose. The most satisfactory results were derived from these poles by attaching pipe cross-arms and no deflection at the middle ordinate of the pole was discernible.

The United Electric Railways Company, of Baltimore, has used cement trolley poles with good results.

Mr. Alexander Crawford Chenoweth, of Brooklyn, made, in 1906, some cement poles 60 ft. long and 14 in. in diameter, calculated to withstand a direct pull of eight tons and a torsion from a yard-arm 4 ft. long equal to four tons. These poles, erected in place, cost $2.50 a foot. They were built to carry a 4-in. cable, high power, direct current transmission, the spans being 500 ft.

Mr. J. B. McKim, superintendent of the Western Division of the Pennsylvania lines west of Pittsburg, made and set up last year in the line along the Pittsburg, Fort Wayne and Chicago Railway, near Naples, Ind., fifty-three concrete poles of very graceful proportions, in which the method of reinforcement used differs essentially from any other of the poles referred to herein. These poles are small in section and approach the minimum in weight. They have thus far given entire satisfaction and show no evidence of decay.

TABLE SHOWING RESULTS OF THREE TESTS ON POLE NO. 1, CONCRETE, DIAGONAL.

Length 30 ft.	Base Diameter 14 in.	Top Diameter, 8 in.	Depth in Concrete Anchorage, 5 ft.	Distance from Point of Fulcrum to Point of Load. 24 ft. 2 in.

Deflection at Top.	Load Pounds.		Deflection 12 inches above Ground Line.	Time.
		TEST NO. 1.		
3¾ in.	1,830		$\frac{1}{32}$ in.	3 : 17
5¾ in.	2,230		$\frac{1}{16}$ in.	3 : 18
		TEST NO. 2.		
½ in.	50	Temporary deflection, ½ in.	$\frac{1}{32}$ in.	......
8 in.	2,630		⅛ in.	3 : 19
11¾ in.	3,030	Crack No. 1 and 2	$\frac{3}{16}$ in.	3 : 20
		TEST NO. 3.		
1¼ in.	50	Temporary deflection	$\frac{1}{16}$ in.	......
14¼ in.	3,430	Crack No. 3 and 4	¼ in.	3 : 24
18 in.	3,210	Crack No. 5 and crushed bolt	⅜ in.	4 : 25
25½ in.	3,150	Pole broke at ground level	¾ in.	3 : 26

A notable example of recent construction of a pole of mammoth proportions is that of the reinforced concrete tower for the West Penn Railway Company's transmission line, spanning the Monongahela River at Brownsville, Pa. This structure, which is 150 ft. in height, supports cables through a span of 1,014 ft., crossing the Monongahela River. The cables are attached at an average height of 105 ft. from the base of the pole, which is backed up by a shorter structure of the same construction, used as an anchorage tower. Both towers were designed as cantilever beams and are mentioned as examples of how these erections are extending. The details of construction are outlined by Mr. F. W. Scheidenhelm, who designed and constructed the towers, in an article published in the issue for May 2nd, 1907, of the *Engineering News*.

After a somewhat extensive series of experiments, made some time since, Mr. J. L. Weller, member of the Canadian Society of Civil Engineers and superintending engineer of the Welland Canal, built and erected a power line along the Welland Canal, used reinforced concrete for the manufacture of the poles. The poles in this line stand from 45 to 70 ft. in height and were designed to withstand a horizontal pull at the top equivalent to 2,000 lb. These poles have been standing in the line for more than three years and are apparently in good condition. I am informed that Mr. Weller also built a line of concrete poles 40 to 60 ft. in height for the Niagara Falls Power Company and a line twelve miles long from DeCow Falls to Welland for the Hamilton Cataract Light, Power and Traction Company, the poles running from 30 to 40 ft. in height above the ground. Short, heavy stubs are used to carry the line over the gorge at DeCow Falls, and poles 68 ft. high carry the span of 400 ft. crossing the Welland River.

The poles themselves in the latter case are erected in the centre of square concrete piers on pile foundations and are capable of standing an immense strain. He also made a pair of concrete poles 150 ft. in height for the Lincoln Electric Light and Power Company to carry that company's wires over the old Welland Canal at Lock Three, St. Catherines, Ont. These poles are 11 in. square at the top, 31 in. square at the base and weigh about 45 tons each. They were made, not built up, from the base like the towers at Brownsville, Pa., above referred to, but horizontally on the ground and, as is the practice with wooden poles, raised into position. Of course, their extreme height and weight made it necessary to use special apparatus for their erection. Mr. Weller's processes of reinforcement are covered by patents.

Recurring briefly to the relative merits of the reinforced concrete poles as compared with the wooden pole restumped with concrete above referred to, it is thought that, while quite a considerable output of the latter have been manufactured and used, unless some more secure arrangement for uniting the two parts in the restumping process shall be adopted, and one that can be secured at a low cost, this solution of the problem of supplying a substitute for the wooden pole will not be a lasting success. Another point that may be cited as against the use of the stumped pole is that the greatly increased cost, by reason of putting on a sufficiently stable brace, will not be justified by the short additional life secured for an old pole by the restumping process.

It is expected that within a few weeks some steel poles with just enough concrete to serve as a preservative, and other steel poles covered experimentally with a cement paint, will be set in the line along the Fort Wayne Road. Experiments have also been made with several sizes of reinforced concrete cross-arms with very satisfactory results.

The tests at Rochester, Pa., were made by Mr. Robert A. Cummings, who built the poles for the Pennsylvania Railway in his yards at that point.

We are indebted to our contemporary, *The Cement Age*, of New York, for the photographs illustrating this article.

OTHER NEW USES.

The Application of Concrete in Mines.

Concrete Supports in Mines.—The effort to obtain durable and lasting mine supports to supplant the costly and destructible timber commonly used has led to experiments in this direction with concrete. It is now stated in *Mines and Minerals* that some very successful applications of concrete construction have been made in the collieries of the Philadelphia & Reading Coal & Iron Co., near Shamokin, Pa., in the replacement of timber for roof support by concrete. At the Burnside colliery there is a turnout in the No. 8 seam a short distance from the foot of the shaft. The No. 8 seam is the bottom split of the Mammoth seam, which in the Shamokin region is divided by a parting of considerable though varying thickness into two seams, locally known as No. 8 and No. 9.

The seam pitches about 65 deg. to the south. Owing to the pitch of the seam a large part of the weight of the coal between the turnout and the airway rests on the turnout roof supports. The coal itself rarely loosens *en masse* from its walls, but the slate, etc., located between the two principal benches of coal parts easily from those benches and bears heavily on the turnout roof supports. This weight formerly caused frequent breaking of the heavy timber collars used on the turnout.

The turnout is 20 ft. wide on the bottom, and the gangway, ordinarily, is 12 ft. wide. The gangway, for the greater part of its length, as well as the turnout, is heavily timbered, the sets consisting of from 14 in. to 16 in. legs and collars, lagged with from 4 in. to 6 in. round timber, the sets being placed at 5 ft. centres.

Owing to the frequent breaking of timber on the turnout, and the necessity for immediate and frequent repairs, it was decided to try concrete arches for roof support. The first of these arches was completed on March 21st, 1906. Since then, 14 more arches have been constructed from time to time. Since the arches have been put in they have not shown any sign of weakness, and not the smallest crack can be detected.

The concrete frames, or forms, for the arches were made of 1 in. by 8 in. boards, braced by 2 in. by 6 in. scantling. They were constructed immediately adjacent to the timber sets. After the concrete had set, in some two weeks, the timber supports were removed, leaving the old lagging of 4 in. to 6 in. round timber resting on the concrete. As these decay they will be replaced with old 25-lb. mine rails.

The first five arches were built about 24 in. sq., in cross-section, as an experiment, but the last ten were only 18 in. sq., but they seem to stand the strain equally well.

The first arches were stiffened by old 25-lb. mine rails. Two rails, bent to conform, were placed in each arch, one near each lower edge, 3 in. from the bottom and 3 in. from the side. Each concrete leg contained two rails similarly placed near the edges facing the turnout. In the later constructed arches, worn steel rope, woven back and forth through the concrete, was used in place of the old rails. Although the majority of the arches were built with concrete legs, several were built into hitches cut into the top and bottom slate, some 3 ft. below the turnout roof. These have stood the strain as well as the arches supported by concrete legs, and it is probable that the arches constructed in the future, when possible, will be built into similar hitches, thus lessening the cost of construction.

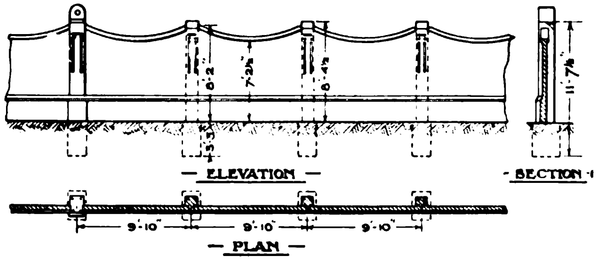
As the timbermen, who constructed the arches, worked on them at intervals, when not engaged upon more pressing work, the labour cost is hard to determine accurately. The time, however, is estimated by P. F. Brennan, division superintendent, as from 3 to 4 days for four men continuously employed, as follows: One mixer, two concrete placers, and one rammer, the arches of 18-in. section requiring about 3 days.

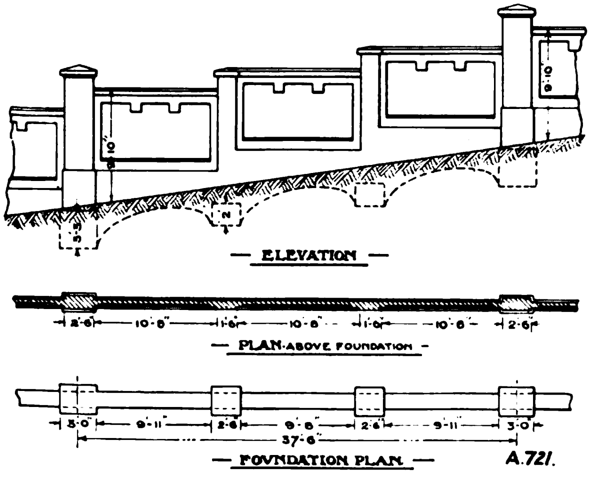
The concrete was hand-mixed on a platform, and the usual 1-3-5 mixture was used.

Mr. Brennan estimates the total cost per arch to be £5 10s. (American cost) for those of 24-in. section, and £4 2s. for those of the 18-in. section. Ultimately the timber on the turnout will be entirely replaced by concrete arches.

A Concrete Fly-wheel.—At a recent meeting of the Transvaal Institute of Mining Engineers, a paper was read by Mr. W. D. Younger, describing a novel use of concrete in a fly-wheel designed by Mr. D. Leitch, M.I.C.E. A discussion then took place with reference to the stresses set up in the steel frame and concrete, and the balancing of the fly-wheels. In the course of the discussion Mr. Ostreicher mentioned an instance where a large grindstone, over 15 ft. in diameter, had been used as a fly-wheel on account of the high cost of iron, and Mr. A. Wallace pointed out that spur wheels, filled in with concrete, had been running for two and a half years at the Robinson Deep Mine.

Supports for Electric Cables.—A very interesting paper, by Mr. D. W. Krellwitz, is to be found in the *Proceedings of the American Society of Civil Engineers*, describing the reinforced concrete towers built and erected for the Lincoln Light and Power Co., on each side of the old Welland Canal, in the province of Ontario, to support the cables transmitting current from the transformer plant to St. Catherine's. These towers are 142 ft. high above ground level, being 31 in. sq. at the bottom and 11 in. sq. at the top. The case of each tower is a 10-ft. cube of concrete, in which 8 ft. of the reinforced tower is embedded. Towers of the great size here described are not wanted at present in Great Britain, but the fact that they have been adopted in Canada, where timber is comparatively cheap, should encourage the adopting of reinforced concrete by our own Post Office, railway companies, and electric power companies.





A.721.

Reinforced Concrete Boundary Walls.—We reproduce here an illustration of a reinforced concrete wall for a factory at St. Polten, in Austria. The wall is 1,000 metres long. We also give an illustration of a boundary wall to a home and hospital near Vienna. This wall was 1,800 metres long. Both walls were carried out by local reinforced concrete specialist firms.

TESTS WITH CONCRETE

AT HOME AND ABROAD.

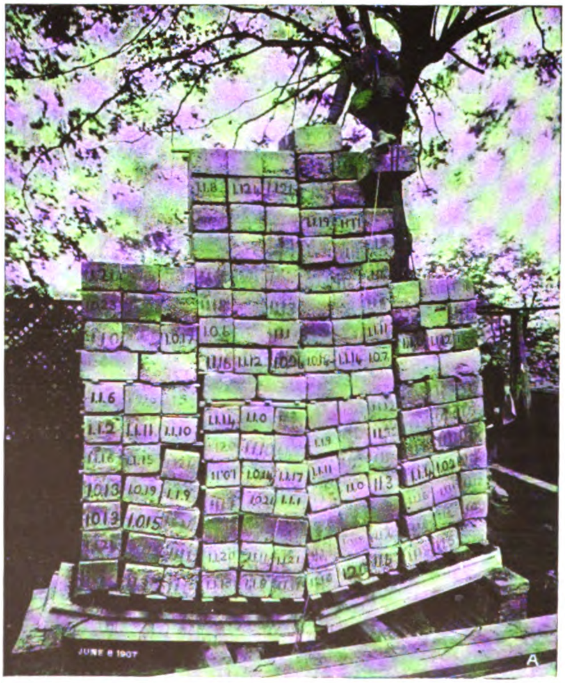
We consider that the absence of reliable information as to the various tests carried out with concrete both at home and abroad has frequently led to misconceptions as to the qualities of this material, and we shall thus for the present accord considerable space to the presentation of authentic data that may be of service to those employing concrete in its various forms. The tests which will particularly call for our attention are those relating to strength, fire-resistance, and waterproofing.—ED.

Load Tests with Reinforced Concrete Floor Slabs.—Reinforced concrete floor slabs, constructed on the Herbst Armocrete Tubular Flooring System, were subjected to a series of load tests by the British Fire Prevention Committee, whose report has now been issued as a supplement to an earlier report dealing with the fire resistance of slabs constructed on this system.

It is eminently instructive to read the report on the load tests in conjunction with that on the fire tests, and there can be no doubt that load tests, carefully conducted by an independent committee, cannot but be useful to the members of the technical professions desiring to obtain reliable information, for makers' private tests are frequently looked upon with askance and all too often mismanaged.

For instance, a private test with a floor on the identical system, which we attended, lacked that thoroughness in arrangement and foresight in preparation which is necessary when reliable data are to be obtained, and for all practical purposes this private test was valueless, both in a positive and a negative sense, for the foundations to the floor slabs under test in these private experiments did not appear to be all that could be desired, and at least in one case, may have affected the results, which will, by-the-bye, be found reported at length in the *Builder* of November 9th, 1907.

As to the official test, there can be no doubt that the results were entirely satisfactory, regardless of the fact that they showed considerable variation. The variation, however, was only to be found after the primary question had been settled—namely, that the breaking point was not within the factor of safety of four, and it was simply a question as to whether the beams would carry four times as much or eight times the estimated load.



A HOLLOW (TUBULAR) REINFORCED CONCRETE FLOOR.
A 14 ft. Span immediately after breaking under a load of 12 cwt. 1 qr.

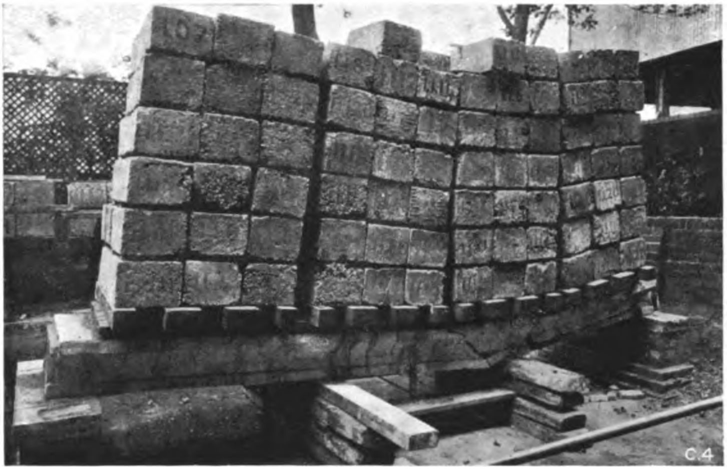
As to the load tests with two beams of 14-ft. span, the breaking point in the first instance was when the slab was loaded with 6 cwt. 2 qrs. per ft. super., when the slab broke in the centre. In the second case the slab broke when loaded to the extent of 12 cwt. 1 qr. per ft. super. In the case of the beam of 28-ft. span, the load carried was 7 cwt. 2 qr. per ft. super., with a deflection of 1·24 in. The load, upon being sustained for 35 days, increased the deflection to 3·95 in., but the slab had not actually broken at the conclusion of the test.

Full particulars are obtainable from Report No. 125 of the British Fire Prevention Committee, which is well illustrated, and a point that might be observed regarding these tests is that the loads were so placed as to avoid any bridging action, that the load comprised concrete blocks, and that these were carefully placed in position with the aid of a crane.

An illustration is shown of the 14-ft. span that broke under a load of 12 cwt. 1 qr., taken immediately after breaking, and similarly one of the other span which broke under 6 cwt. 2 qr. load.

The cement used throughout the satisfactory official tests was that known as the "Ferrocrete" Brand.

The difference in the results, we believe, must be due to some difference in the care applied during the construction of the two slabs under test, for the materials and design throughout were identical.



A HOLLOW (TUBULAR) REINFORCED CONCRETE FLOOR.
A 14-ft. Span immediately after breaking under a load of 6 cwt. 2 qr.

Test with a Reinforced Concrete Roof.—Mr. Ernest Franck, architect of the New Public Baths for the Borough of Hammersmith, recently published in the *Journal of the Royal Institute of British Architects* some interesting data as to tests in connection with the reinforced concrete roofs of these baths.

The building, which is of exceedingly interesting construction, comprised beams and stanchions on the Kahn system, and surfaces reinforced with Expanded metal.

The result of the tests was most satisfactory, and the arrangements, with diagram, as published in the *Journal* named above, may serve as a model for similar tests.

The tests were conducted by Mr. Kirkcaldy, and were undertaken at the instance of the Local Government Board, who, when their sanction was required for a loan for the erection of the building, had informed the Hammersmith Borough Council that their sanction could not be given for any work on walls or roofs of the first-class bath which involved the use of reinforced concrete, but the Board would be prepared to consider the matter further if the Borough Council would undertake to test one or more ribs after erection, in the presence of one of the Board's Engineering Inspectors, such test to be carried out under the supervision of an independent expert.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

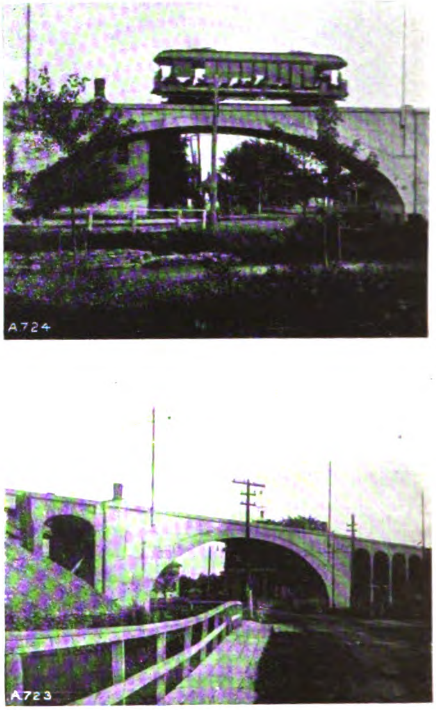
A REINFORCED CONCRETE RAILWAY BRIDGE IN CANADA.

THE Niagara, St. Catherine's and Toronto Railway has recently erected what is probably one of the largest reinforced concrete railway bridges in Canada, which has been constructed over Oak Street, in Merritton, along a canal raceway. The sections of trestle leading up to the bridge at either end are filled in, while the structure has been given sufficient time to thoroughly dry and set.

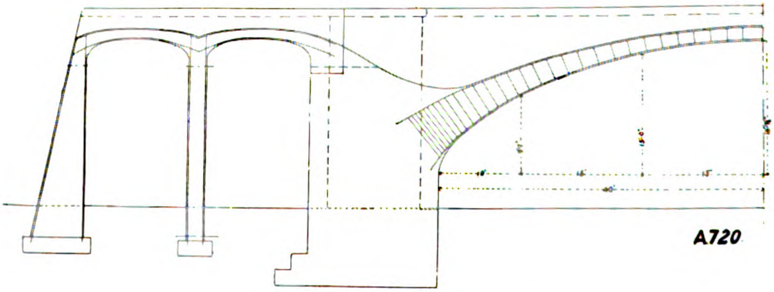
This concrete and steel bridge arches the main street of the village, and consists of one 80ft. clear span, and four 15 ft. spans. Medium steel reinforcements of not less than 60,000 lbs. per sq. in., and an elastic limit of not less than 30,000 lbs. per sq. in., were used throughout. The longitudinal and transverse bars were so fastened together at all intersections as to form a solid network in the concrete.

Three grades of concrete were used in the construction, all of the best Portland cement, clear coarse sand, and clean broken stone free of dust.

The first class was used exclusively for



REINFORCED CONCRETE RAILWAY BRIDGE AT MERRITTON, CANADA (showing main arch of 80 ft. span, the side arches of 15 ft. span).



REINFORCED CONCRETE RAILWAY BRIDGE AT MERRITTON CANADA (Side Elevation).

rims of arches as far as the springing planes, and also on the parapet walls and in wing walls of abutments. It consisted of 1 part Portland cement, 2 of sand, and 4 of broken stone. The second class was used in the body of the piers from the springing plane of the arches to a depth of 4 ft. above the foundations, and the third was used in the foundations of the piers and abutments.

The reinforcements consist on the large arch of 1¼ in. medium steel round bars, 6 in. centres, connected together by turnbuckles. The small arches are reinforced by ¾ in. round steel, 1 ft. centres, while the small piers are reinforced vertically and longitudinally by round steel bars, the spans of walls vertically and longitudinally with twisted steel bars every 3 ft. The rims of arches were deposited in transversal blocks about 10 ft. long, one block being allowed to harden before the next block was deposited.

At the south end of the arch there is a reinforced concrete wing wall 50 ft. long, extending at an angle of 45 deg. with the line of the arch. The base near the arch is 12ft. wide, while 6ft. above it is 5 ft. wide and 1½ ft. wide at the top, which is 27 ft. above the ground. The wall is reinforced throughout with twisted steel bars at the outer underside and the inner upper side of the base as well as vertically and horizontally. The whole structure required 1,300 cu. yds. of concrete and 23 tons of steel, and the main arch, which has a 20 ft. rise, is capable of sustaining two 150-ton locomotives.

We are indebted for our illustrations to the Chief Engineer of the Niagara, St. Catherine's and Toronto Railway Co. of Ontario.

WALNUT LANE BRIDGE, GERMANTOWN, PHILADELPHIA, U.S.A.

We understand that the longest concrete arch bridge in the world, which is now nearing completion, will be the Walnut Lane Bridge, connecting Roxborough with Germantown, U.S.A., which is being erected from the designs of Mr. Geo. N. Webster, of Philadelphia, Messrs. Reilly & Riddle acting as contractors. The main arch has a clear span of 233 ft. The extreme length of bridge is 585 ft., with a width of 60 ft. The roadway is 147 ft. above the Wissahickon Creek.

REINFORCED CONCRETE BRIDGE AT RIXDORF-MITTENWALDER.

Small bridges in reinforced concrete are becoming very popular in Germany, more particularly with the development of the light railways.

We here present an example of a bridge over the Rixdorf-Mittenwalder Light Railway, of which Messrs. Havestadt & Contag, of Berlin-Wilmersdorf, the Consulting Engineers, have kindly placed a photograph and drawings at our disposal, and these, together with the metrical figures practically explain the construction.

The engineers inform us they were instructed to allow for a considerable carrying capacity for the bridges in question, and that a German 23t. steam roller was taken as the basis for the live load.

Round metal rods were used throughout for the reinforcement, and these were thoroughly washed over with Portland cement prior to the concrete being filled in.

The time occupied for the construction of these bridges, after completion of the abutments, averaged twelve working days for each bridge.

The three bridges varied in superficial area—*i.e.*, had respectively an area of 178 sq. m., 200 sq. m., and 116 sq. m. Each crossed the light railway at varying angles of from 57 to 86 deg. The cost of each bridge ranged from 17,600 marks to 25,900 marks (or, say, £850 to £1,275 each).

The actual "bridge plate," as it is described in Germany, including the paving, the cornice, and the hand rails, cost on the average £2 4s. per sq. m. (say, 10 ft.) of bridge surface.

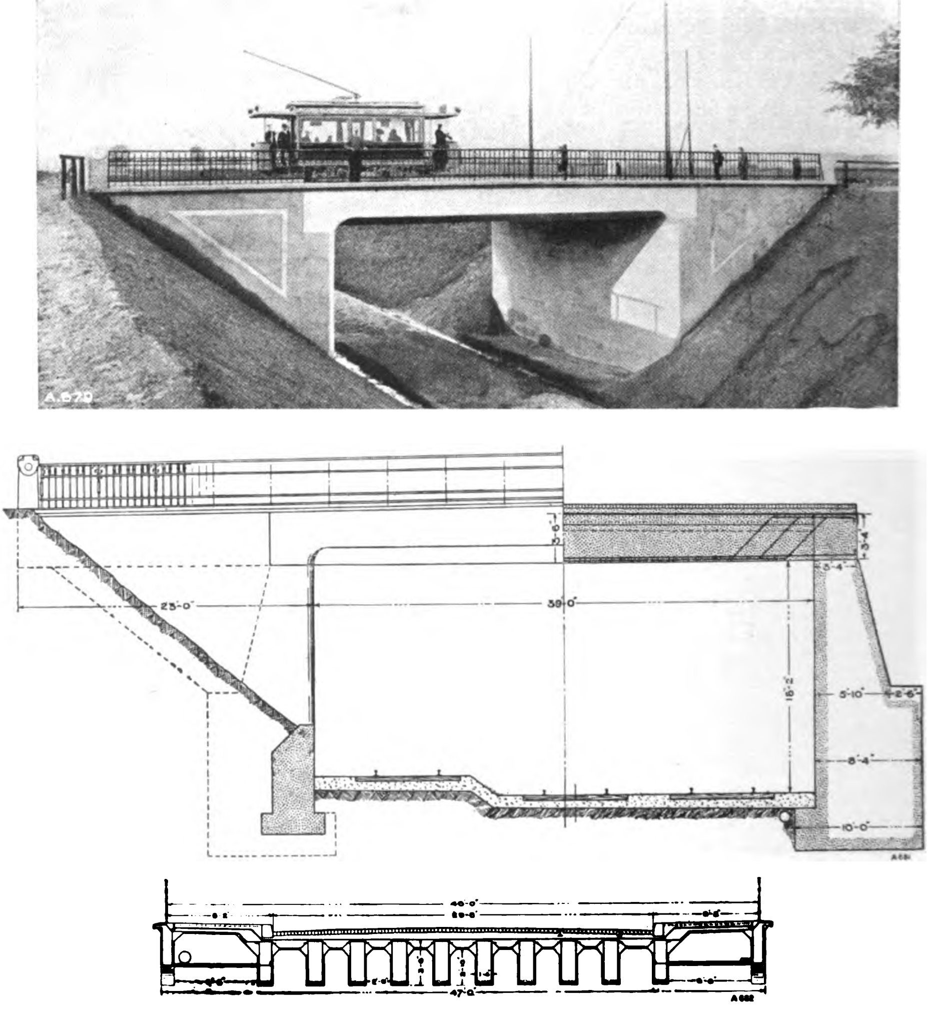
The reinforced concrete work was carried out by the Monier Co., of Berlin.

A REINFORCED CONCRETE VIADUCT IN SPAIN.

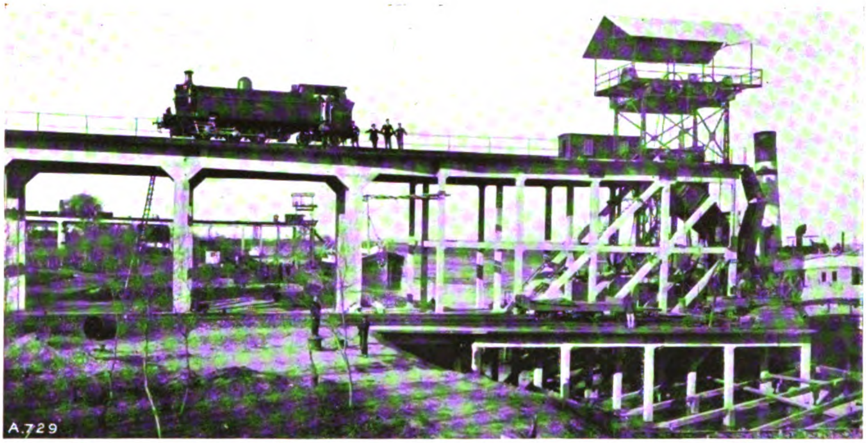
In order to increase its facilities for shipping ore on a large scale, the Cala Iron Co. recently decided to construct a line of rail from their works at Huelva to the wharves in Seville, some 60 miles in length.

The original idea was to build the wharves of timber, connected with the high ground by timber trestles and embankments, but when work had been already begun on the latter, Mr. Juan de Zafra, one of the engineers of the port works, suggested that reinforced concrete should be used on a large scale, and that viaducts of this material should be substituted for the approaches in lieu of embankments and trestle-work.

The result has been the construction of a pair of viaducts which are practically alike in details of construction, having spans of 9 m. between centres of stanchions. The main girders are 1.20 m. deep by 0.23 m. wide, and support platforms 3.5 mètres wide. Details of the main girders are shown in *Fig.* 1. While the cross section is shown in *Fig.* 2. The first six pairs of spans are on a curve of

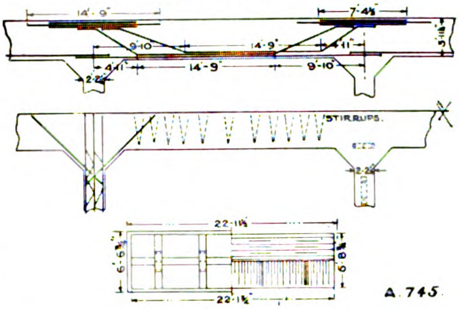


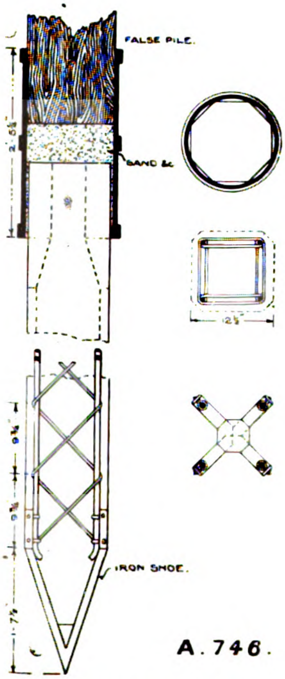
Reinforced Concrete Bridge over a Light Railway at Rixdorf-Mittenwalder.



Reinforced Concrete Viaduct for the Cala Iron Co., Seville, Showing Wharf.

190 m. radius, this being unavoidable on account of an existing embankment. The stanchions supporting the girders form a structure monolithic with the latter. They are of rectangular section, measuring 0.67 m. by 0.23 m., being braced together at the 8 m. and 11 m. levels, some of the very high ones also having bracing at the 13 m. level. The stanchions rest upon slabs of reinforced concrete, which in turn rests on blocks of ordinary concrete.





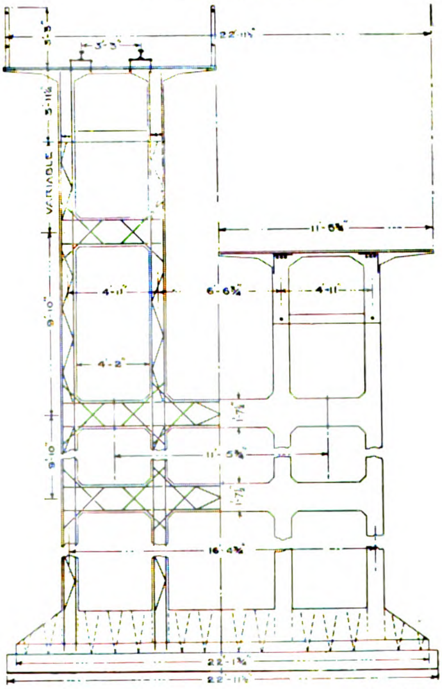
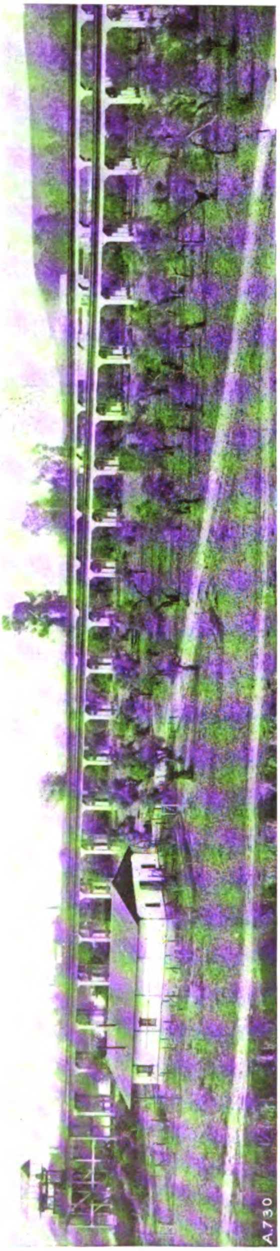


Fig. 3. Details of Piles.

Fig. 1 and 2. Details and Cross Section of Main Girders.

The first portion of the first viaduct has 13 spans of 9 m. each, and the total length, including the already existing embankment, is 117 m.; the second portion consists of nine spans covering some 72 m. in all.



Portion of the Reinforced Concrete Viaduct Erected by the Cala Iron Co., Seville

For the wharf work the columns are braced together by means of two sets of horizontal struts, supporting two platforms reinforced with ribs. In *Fig.* 3 we reproduce details of the piles which were used, the lower portion of each stanchion

A Bridge at Beja, Tunis.

Constructed in Reinforced Concrete on the Hennebique System. Architect, M. Picard. Contractor, M. Peloni. Photograph reproduced by the courtesy of M. Reymond, of Tunis.

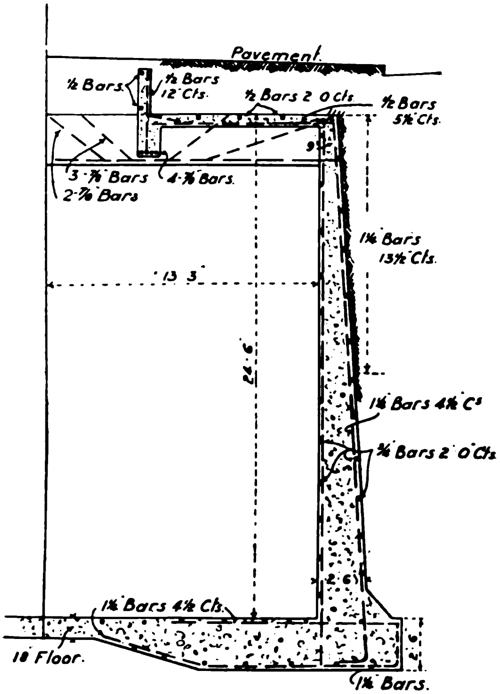


Fig. 1. REINFORCED CONCRETE RETAINING WALL AT ROYAL INSURANCE OFFICES, PICCADILLY, LONDON. Typical Sections.

here being dealt with as a square pile of reinforced concrete.

An elaborate system of tests were made both on the viaducts and piers, all of which were eminently satisfactory.

The time employed in construction of the first viaduct was 8½ months, and the whole structure, including the wharf, cost something over £9,000.

We are indebted for our illustrations to Mr. Juan M. de Zafra, of Seville, the designer of the work, who also acted as contractor.

A RETAINING WALL IN PICCADILLY.

The question of retaining walls to deep cellars is becoming the more important having regard to the fact that in certain classes of buildings it is becoming common to have two or even three basements.

Quite a number of interesting retaining walls of this description are in course of construction in the metropolis. One of these, for the Royal Insurance Offices, in Piccadilly, is being erected by the Empire Stone Co., Ltd., Mr. A. Drew, M.Inst.M.E., acting as engineer.

"Indented" bars have been employed throughout. The typical section shows horizontal beams carrying the pavement, and it should be noted that these beams afford no horizontal support to the wall, as their inside ends must not exert any thrust on the columns on which they rest. The thrust of the earth which carries the heavy loads of the road is therefore entirely taken by the wall.

This arrangement has enabled certain economy to be effected in the bulk of concrete, as can be seen by the thinness of the wall at its base, as compared with the thickness required for a plain concrete wall, and valuable space has been obtained by this method of construction, suitable for cellarage and storage accommodation. *Fig.* 2 shows the vertical bars at the top of the wall, and the old arches which supported the pavement are immediately behind it. The Portland cement used was the "Ferrocrete" brand.

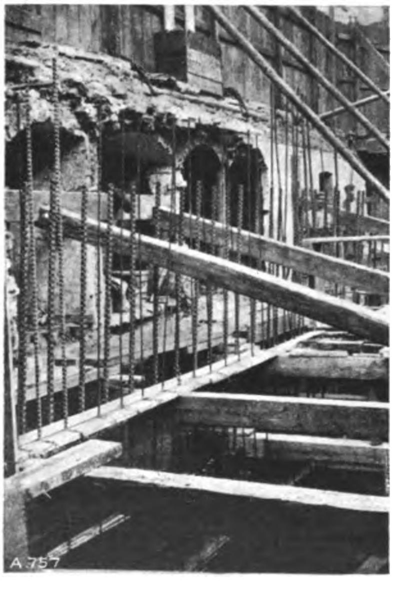


Fig. 2. REINFORCED CONCRETE RETAINING WALL AT ROYAL INSURANCE OFFICES, PICCADILLY. View during Construction.

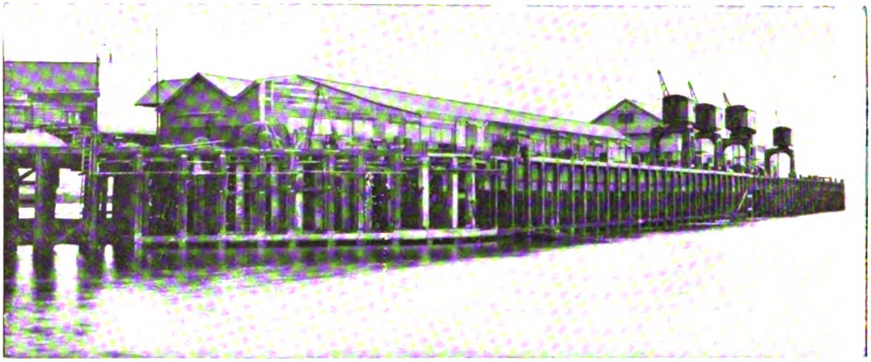
OCT 30 1917

D. G. SOMERVILLE & CO.,

THE SPECIALIST ENGINEERS AND CONTRACTORS IN

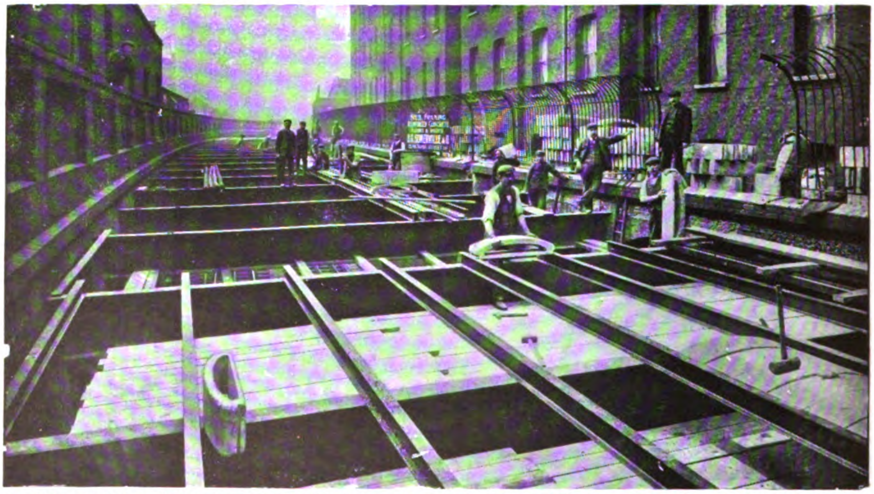
REINFORCED CONCRETE

ILLUSTRATIONS SHOW TWO OUT OF TWENTY-SEVEN CONTRACTS EXECUTED BY US IN REINFORCED CONCRETE IN 1907



TOWN QUAY, SOUTHAMPTON, RECONSTRUCTED BY US IN REINFORCED CONCRETE
(Kahn System)

WE NOT ONLY DESIGN BUT EXECUTE ALL WORK ENTRUSTED TO US AND TAKE FULL RESPONSIBILITY FOR SAME



SOUND-PROOF CONSTRUCTION IN REINFORCED CONCRETE. COVERING IN DISTRICT RAILWAY ON OUR SYSTEM OF HOLLOW REINFORCED CONCRETE TILES.

We have prepared an elaborate Handbook describing and explaining the various systems of Reinforced Concrete, and giving concise calculations for the design of structures. Send us a postcard and we will send you a copy. We can save clients time and money, as owing to our experience we know the system most suited for each particular case.

72 VICTORIA ST., S.W. **Works: SOUTHALL**